



Shaping Tomorrow's  
Built Environment Today

## MINUTES

### Refrigeration Committee (REF)

January 21, 2018

Palmer House Hilton

Chicago, IL

#### MEMBERS PRESENT:

Nick Shockley, *Chair*  
Martin Dieryckx, *Vice-Chair*  
Walid Chakroun  
Didier Coulomb  
Stephen Gill  
Charles Hon  
Yunho Hwang  
Barbara Minor  
Rajan Rajendran  
Jason Robbins, *Consultant*  
Dave Rule  
Ginger Scoggins, *CO*  
William Walter, *BOD Ex-O*

#### MEMBERS NOT PRESENT:

Shamila Nair-Bedouelle  
Richard Royal

#### ASHRAE STAFF:

Steve Hammerling, AMORTS

#### GUESTS:

Karim Amrane  
Neil Bulger  
Jim Caylor  
Ayman Eltaloung  
Felix Flohr  
Kit Fransen  
Brian Fricke  
Grace Gad  
Elizabeth Goll  
Glenn Hourahan  
Rainer Jakobs  
Allen Karpman  
Georgi Kazachki  
Alero Miyara  
Shon Okubo  
Jose Romanillos  
Ivan Rydkin  
Mick Schwedler  
Vishal Sharma  
Daryl Stauffer  
Jim Wolf  
Shitong Zha

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## MOTIONS

No.	Motion	Status
1	the minutes from the REF Annual Meeting in be approved.	PASSED
2	REF aim to comment on UNEP Refrigeration Technical Options Committee (RTOC) later this year.	PASSED
3	REF recommends to Technology Council, to increase the Committee Travel budget for FY 18-19 from \$7.7k to \$8.4k and to reduce Awards and Certificates budget from \$1.4k to \$0.7k.	PASSED

## ACTION ITEMS – Winter 2018

No.	Responsibility	Action Item	Page
1	REF	Send comments on draft ASHRAE Strategic Plan to send to Shockley to collect and send to Tech Council	2
2	REF	Solicit nominations for the Milt Garland and Comfort Cooling Awards for May 1 <sup>st</sup> deadline.	2
3	Staff	Promote REF awards (the usual activities, to contact Refrigeration Vice-Chairs (RVCs) and chapter refrigeration chairs)	2
4	REF	Recruit DL speakers for CTTC topics of interest	3
5	Walter	Review requirements for REF to participate in regulatory public reviews on technical issues	5
6	REF	Review and propose changes to REF title/scope for spring conference call	5

## ACTION ITEMS – Annual 2017

No.	Responsibility	Action Item	Status
LB-1	Chakroun	Chakroun agreed to find out where discount for ASHRAE members to IoR publication currently stands with ASHRAE	Complete
LB-2	Staff	Staff agreed to determine if REF should more formally approve IoR discount to ASHRAE members	Complete
LB-3	REF and Staff	REF will review what can be done to generate more Milt Garland and Comfort Cooling nominations.	Complete
LB-4	Staff	Collect Journal articles eligible for Briley Award and send to judging subcommittee for their review	Complete
LB-5	Shockley	Shockley agreed to inquire with Royal and report on status of refrigeration related ALI course	Complete
LB-6	REF	REF was asked to nominate Distinguished Lecturers related to flammable refrigerants	Complete
LB-7	Staff	Submit Ivan Rydkin name as volunteer to be DL on flammable refrigerants	Complete
LB-8	Shockley	Review EPA/DOE RFI to see if/how REF should participate	Complete
LB-9	Hamilton	Prepare and work with REF chair to give a presentation on natural refrigerant perspective to REF at a future meeting	Ongoing
LB-10	Shockley	Review REF's strategic planning issues and include prioritized list for 2017-18 SY as appropriate.	Complete
LV-8	Royal and Robbins	Attend Associate Society Alliance meeting in Las Vegas and report to REF in spring.	Ongoing

LV-9	Amrane	Develop a presentation from REF to outside groups such as USNC IIR and ASHRAE Associate Society Alliance organizations on how REF can liaise and interact with these sorts of groups	Ongoing
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#### LIST OF ATTACHMENTS

No.	Attachment
A	BOD Ex-O Presentation
B	UNEP/ASHRAE Partnership Presentation
C	UNEP brochures
D	CTTC report
E	Regulatory Update Presentation
F	A2L Refrigerant update
G	GCCA Liaison report
H	2017-18 MBOs

#### LIST OF ACRONYMS

AHJ	Authority Having Jurisdiction	IIAR	International Institute of Ammonia Refrigeration
AI	Action Item	IIR	International Institute of Refrigeration
ALI	ASHRAE Learning Institute	IoR	Institute of Refrigeration
AMORTS	Assistant Manager Research & Technical Services	MBO	Management by Objectives
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers	MTG	Multi-disciplinary Task Group
BOD	Board of Directors	PD	Position Document
CNV	Chair Not Voting	PI	Principle Investigator
CO	Coordinating Officer	PMS	Project Monitoring Subcommittee
CTTC	Chapter Technology Transfer Committee	REF	Refrigeration Committee
DL	Distinguished Lecturer	RFI	Request for Information
DOE	Department of Energy	ROB	Rules of the Board
DRSC	Document Review SubCommittee	RP	Research Project
EPA	Environmental Protection Agency	RTOC	Refrigeration Technical Options Committee
Ex-O	Ex-Officio	RVC	Regional Vice Chair
		SSPC	Standing Standard Project Committee
GCCA	Global Cold Chain Alliance	SY	Society Year
GRMI	Global Refrigerant Management Initiative	TC	Technical Committee
GWP	Global Warming Potential	UN	United Nations
HVAC&R	Heating, Ventilation, Air Conditioning & Refrigeration	UNEP	United Nations Environment Programme

## **1. CALL TO ORDER**

Chair Nick Shockley called the meeting to order at 8:00 AM. Members and guests introduced themselves. Shockley confirmed quorum was met.

## **2. ASHRAE CODE OF ETHICS COMMITMENT**

Shockley quoted the ASHRAE Code of Ethics from the agenda - 'In this and all other ASHRAE meetings, we will act with honesty, fairness, courtesy, competence, integrity and respect for others, and we shall avoid all real or perceived conflicts of interests.' (See full Code of Ethics: [www.ashrae.org/about-ashrae/ashrae-code-of-ethics](http://www.ashrae.org/about-ashrae/ashrae-code-of-ethics).)

## **3. REVIEW OF AGENDA**

No changes were suggested to the meeting agenda sent ahead of meeting.

## **4. MINUTES**

A. It was moved (RR) and seconded (CH) that,

(1) the minutes from the REF Annual Meeting in be approved.

**MOTION 1 PASSED:** 9-0-0, CNV

**BACKGROUND:** Minutes were distributed in July 24<sup>th</sup> email.

## **5. CHAIR'S REPORT – Shockley**

A. Motions from Past Meetings Requiring Higher Body Approval

There were no motions from past REF meetings required higher body approval.

B. New Information Items for REF

Shockley intended to address two issues later on agenda for further discussion:

- Review of Refrigeration Committee scope
- Can REF help ASHRAE participate in regulatory proposal reviews?

## **6. VICE-CHAIR'S REPORT – Dieryckx**

A. Fiscal Report

Dieryckx noted the travel budget for committee members is typically underfunded. REF will review later on agenda to see if changes should be recommended.

B. MOP/ROB/Reference Manual

No changes for this meeting to these documents. REF will review the committee name and scope in the ASHRAE Rules of the Board (ROB) to assure it accurately reflects and communicates the committee's activities and objectives. The current title, purpose and scope is as follows:

### *2.420 REFRIGERATION COMMITTEE*

#### *2.420.001 SCOPE AND PURPOSE*

*The Refrigeration Committee shall encourage advancement of refrigeration technology and its application.*

#### *2.420.002 MEMBERSHIP*

##### *2.420.002.1 Composition*

*A. The members of this committee are as follows Twelve (12) voting members, including a chair and a vice chair,*

*B. Non-voting members include a Board ex-officio member and coordinating officer.*

*2.420.002.2 Qualifications (84-02-02-25/86-01-23-42/99-06-24-36)*

*Committee members should be refrigeration-oriented persons and should include a cross-section of the refrigeration industry.*

*2.420.002.3 Term of Service (85-06-26-11/86-06-25-09/94-06-26-04/99-01-28-80/00-02-10-64B)*

*The term of service for voting members is intended to be three (3) years, subject to ROB 3.300 Election and Appointment Procedures.*

*2.420.003 OPERATION*

*2.420.003.1 General Requirements (07-06-27-34)*

*A. This committee shall coordinate and promote chapter, regional and Society activities in the field of refrigeration.*

*B. This committee is responsible for developing programs which allow the Society to participate with other organizations in education and technology transfer in the field of refrigeration.*

## **7. BOD/TECH COUNCIL REPORTS**

**A. BOD EX-Officio – Walter**

Walter presented the Ex-O presentation (**Attachment A**). Highlights include:

- Nominations for REF and other committees sought for SY 18-19. See [www.ashrae.org/nominate](http://www.ashrae.org/nominate)
- ASHRAE received Partnership Award from the UN Environment Ozone Secretariat: Held in Toronto, Canada, November 2017
- New Region XIV established with regions in Europe
- New Global Training Center for Building Excellence in Dubai
- 2019-2024 ASHRAE Strategic Plan in development.

Walter thanked all for time and service to ASHRAE activities and asked for any feedback from committee members to take to the BOD.

**B. Coordinating Officer – Scoggins**

Scoggins thanked REF for their work and asked anyone with input on Strategic Plan to send to Shockley to collect and send to Tech Council (**AI #1**).

## **8. AWARDS**

**A. Milt Garland & Comfort Cooling Awards**

Nominations for the Milt Garland and Comfort Cooling Awards are due by May 1<sup>st</sup> deadline. REF members were asked to promote the awards and solicit project nominations (**AI #2**).

Staff would work to promote the award with the usual activities but also to contact Refrigeration Vice-Chairs (RVCs) and chapter refrigeration chairs. (**AI #3**).

**B. Briley Award**

The 10<sup>th</sup> annual George C. Briley Award for the best refrigeration-related article published in the ASHRAE Journal was presented to Mr. Stephen Kujak, for his article “*Flammability and New Refrigerant Options*”.

## **9. SUBCOMMITTEE REPORTS**

**A. ASHRAE Learning Institute (ALI) – Royal**

Royal was not in attendance but had reported a course was nearing completion.

**B. Programs – Hwang**

1. Chicago:

The following programs were approved and will be presented in Chicago:

- Workshop 5 - *Status of Standards in Europe and the Relation to IEC, ISO in View of the Application of Low GWP Refrigerants*
- Seminar 45 - *What In the World? Global Refrigerant Regulations Explained By Experts from Around the Globe*

2. Houston

REF discussed a number of possible programs for the Annual Meeting:

- 1634 training (sustainable refrigeration design)
- Recent advances in solid state cooling (rejected Chi submission)
- Cooling with renewables? (solar)
- Linkage between refrigerant and energy efficiency
- Noted track on HVAC&R for Houston
- Recent Flammable refrigerant research program (after Houston meeting)
- Alternative refrigeration technologies for cold chain

C. Position Documents (PD)

1. *Refrigerants and their Responsible Use* PD

Rajendran reported that the PD committee submitted a draft to DRSC in fall. DRSC provided comments and suggested revisions. The PD committee has reviewed and incorporated a majority (estimated at 80%) of DRSC comments and is meeting later this month to consider and address the remaining comments. A revised draft is expected before Spring 2018.

D. UNEP/ASHRAE Partnership

Ayman Eltaloung presented on behalf of Nair-Bedoulle (**Attachment B**) celebrating 10 years of cooperation between ASHRAE & UNEP. Highlights from the presentation include:

- Three international conferences
- Refrigerants literacy and university level refrigerant management courses
- UNEP/ASHRAE assessment program: Sustainable Operation & Maintenance of Air Conditioning and Refrigeration plants
- UNEP awarded ASHRAE their Award for Climate Protection through Innovation in Refrigerant Management at MOP-29.

Chakroun added that ASHRAE now has a staff office in Dubai to help support chapters and members in the region.

Coulomb referred to brochures developed for developing economies (**Attachment C**). These are on IIR and UNEP websites as well. Chakroun emphasized Dubai training center discussed earlier as an international resource on refrigeration topics.

## **10. OTHER REPORTS**

A. Chapter Technology Transfer Committee (CTTC) Liaison Report – **Hon**

Hon attended CTTC meetings in Chicago and gave a REF report to CTTC (**Attachment D**).

Highlights include:

- CTTC has asked for more Distinguished Lecturers (DL). CTTC will ask each chapter to have one chapter meeting with a refrigeration topic.
- Need legal viewpoint on new refrigerants. Local AHJ questions, etc.

REF agreed to put out a call for DLs on these topics (**AI #4**).

B. Consultant Report

REF reviewed and approved final report to RP-1634, *Guide for Sustainable Refrigerated Facilities and Refrigeration Systems*, in a fall letter ballot. The publication is not available in Chicago but will be published and made available shortly. Shockley thanked everyone for their quick review.

C. Regulatory Update - **Amrane**

Amrane presented a report on Regulatory Issues at the meeting (**Attachment E**). Highlights include updates on the following:

- Many equipment related rulemakings to start in 2018 from the DOE and EPA
- Refrigerant related regulatory activities from ECCC, CARB
- A number of Safety Codes and standards (ASHRAE Standard 15, UMC, IEC) are up for revision in 2018. Some are expected to include comments on 2L refrigerants.
- Amrane updated the group on Montreal Protocol Developments including the Kigali Agreement (US Senate ratification is unclear) and a listing of future meetings.
- Summary of flammability refrigerants research from AHRI, ASHRAE and DOE.

Amrane noted it was unclear how or if regulations would proceed given the current regulatory climate and various lawsuits.

D. Global Refrigerant Management Initiative (GRMI) update – **Chakroun**

Chakroun noted the GRMI has not met since Long Beach so he did not have updates for REF at this time. A subcommittee on refrigerant driver licenses is meeting now. A document has been development and will be sent for review by ASHRAE (and other stakeholders) shortly.

E. ASHRAE 2L research updates

A2L research is summarized in the document (**Attachment F**) sent ahead of the meeting. There will be a related program here in Chicago. Barbara Minor stated she is on the project monitoring subcommittee (PMS) for the ASHRAE research and there is a great principle investigator (PI). There was a delay to do more testing for model development. The Multiple-disciplinary Task Group (MTG) is meeting in Chicago immediately after the REF meeting.

F. Liaisons

1. TCs & SSPCs

REF will continue to liaise with relevant ASHRAE TCs and SSPCs. Please continue to attend meetings and report as appropriate.

2. International Institute of Refrigeration (IIR) - **Coulomb**

Coulomb updated REF on IIR activities of interest. ASHRAE is working with IIR to harmonize their list of definitions (available on IIR website for fee). The next IIR congress is in Montreal August 2019 (<http://icr2019.org>).

3. International Institute of Ammonia Refrigeration (IIAR) – **Rule**

Rule updated REF on IIAR activities. A number of IIAR Standards (2, 6, 7 & 9) would be out for public review in February and he asked all to participate at [www.IIAR.org](http://www.IIAR.org). The next IIAR conference would be March 18-21 in Colorado Springs.

4. Global Cold Chain Alliance (GCCA) liaison report

Liaison Ron Vallort sent his report (**Attachment G**) which was sent to committee with agenda.

## **11. STRATEGIC ISSUES**

A. Management by Objectives (MBO) Updates – MBO leaders



Shockley reviewed MBOs for the current Society Year. Updates will be reported to Tech Council (**Attachment H**).

1. MBO #4 - ASHRAE policy commentary on REF related issues

Shockley noted he wished to focus on regulatory issues from EPA, UN and DOE and asked if ASHRAE should take positions on these issues that affect membership. REF could suggest positions to the BOD for consideration. ASHRAE's Washington DC office does have relationships with US organizations. ASHRAE should be careful in international activities. If considered as American point of view, it may be counterproductive.

BW agreed to look at requirements for this to happen and how it needs to work (**AI #5**). REF would have to determine who to work with (BOD, GGAC, Advocacy, etc.) comply with ASHRAE rules, and determine appropriate timelines and procedures.

It was moved (MD) and seconded (CH) that

- (2) REF aim to comment on UNEP Refrigeration Technical Options Committee (RTOC) later this year.

**MOTION 2 PASSED:** 8-0-0, CNV

REF established a framework to participate in the review and public comment on refrigeration-related regulations and will participate in a technical review of the UNEP Refrigeration Technical Options Committee (RTOC) in June or July 2018. The aim is for REF to be a resource to ASHRAE (from a technical perspective) on regulations that impact ASHRAE members. If successful, REF will use this framework to participate in other reviews of regulation proposals.

2. MBO #5 - Effective communication and operation of the REF Committee (Shockley, Dieryckx, past chairs)

Shockley referred REF again to the scope and purpose of REF in the ASHRAE Rules of the Board. He suggested REF review and make it clearer that REF's scope is more than just industrial refrigeration and refrigerants, it should include all matters related to the refrigeration cycle.

Shockley asked all REF members to review and propose changes to REF title/scope for spring conference call (**AI #6**).

B. Tech Council Innovative Ideas

REF agreed to submit the following item to Tech Council's Innovative Ideas list:

*TOPIC:*

Assure ASHRAE membership has access to current and state of the art technical expertise and speakers on refrigeration and refrigerants related topics.

*PROPOSED SOLUTION:*

Allow and facilitate Distinguished Lecturer (DL) presentations to be given remotely to Chapters.

*PROPOSED ACTION:*

REF proposes the DL program utilize remote presentations. CTTC has indicated trouble finding

refrigeration experts on these topics. Travel time and costs can contribute to difficulties in getting speakers. Remote presentations would help reduce these barriers.

## **12. NEXT MEETING**

REF will hold a spring web meeting in March or April as needed. REF will next meet face to face at the ASHRAE Annual Meeting in Houston, TX on Sunday, June 24, 2018 from 8a-12pm.

## **13. OTHER**

### **A. REF budget**

Dieryckx noted the REF member travel budget has been going over budget in recent years while the budget for awards has underspent.

It was moved (MD) and seconded (WC) that,

- (3) REF recommends to Technology Council, to increase the Committee Travel budget for FY 18-19 from \$7.7k to \$8.4k and to reduce Awards and Certificates budget from \$1.4k to \$0.7k.

**BACKGROUND:** REF has overspent the budget on committee travel, in part due to the high number of international membership. REF has also underspent on Awards, so it is suggested the funds be moved to help assure adequate funds.

**MOTION 3 PASSED:** 8-0-1 CNV

## **14. ADJOURNMENT**

Committee adjourned at approximately 11:45 AM.



## ASHRAE UPDATE

ExO Report to Committees  
2018 Winter Conference



## ASHRAE Wants YOU!

- Standing committee appointments sought for 2018-19
- Join President-Elect Shelia Hayter as she works to position ASHRAE to be the industry leader in the transition toward fully optimizing building energy performance
- [ashrae.org/nominate](http://ashrae.org/nominate)
- Nominations due by February 15




## Presidential Initiatives – Extending Our Community

President's Luncheon Preview

- Global community
- Technological horizon
- Value to members




## Presidential Initiatives – Extending Our Global Community

President's Luncheon Preview



- Partnership Award from the UN Environment Ozone Secretariat: Held in Toronto, Canada, November 2017
- Second Developing Economies Conference: Held in Delhi, India, November 2017
  - Brought together engineers, building professionals and policymakers
  - Addressed infrastructure and urbanization challenges in developing economies.
- First CRC Region XIV Europe: Held in Belgrade, Serbia, December 2017
- ASHRAE Associate Society Alliance (AASA): Brussels, Belgium, April 22-23, 2018
  - First meeting outside of North America
  - A forum where 65 professional societies from around the world exchange knowledge and ideas in the arts and sciences of HVAC&R from a global perspective.
  - Currently investigating an evolution into a Global HVAC&R Alliance



## Presidential Initiatives – Extending Our Global Community

President's Luncheon Preview



**NEW - Region XIV**

- Established July 1, 2017
- 1,800 members
- Close collaboration with REHVA and CIBSE

**Chapters:**

- Cyprus
- Greece
- Ireland
- Portugal
- Spain
- United Kingdom – Midlands
- United Kingdom – London and South-East
- Danube

Additional chapters coming in 2018



## Presidential Initiatives – Extending Our Technological Horizons

President's Luncheon Preview



- Multi-Family Residential Research Project/90.2: To deliver residential building energy performance that is *at least* 50 % more efficient than the energy efficiency defined by the 2006 International Energy Conservation Code.
- IAQ Conference Series Extended: Goal of partnering with the new *Indoor Environmental Quality Global Alliance* (IEQ-GA).
- Air Infiltration and Ventilation Center Partnership (Coming Soon): To give ASHRAE members full access to their growing library of information.



## Presidential Initiatives – Extending Value To Our Members President's Luncheon Preview



- ASHRAE Technology Portal: Subscriber based access to all conference papers in Chicago as well as transactions from Long Beach and other conferences.
- ASHRAE's Reinvestment of Research Dollars: Of the almost \$2.7 million raised in Society Year 2016-2017, \$2 million went to research projects.
  - ASHRAE matched this amount doubling the support for research.
- Solar Decathlon: Eleven teams participated. ASHRAE was a sponsor and provided judges.



## Presidential Initiatives – Extending Value To Our Members President's Luncheon Preview



- New Building EQ Portal: Launched December 2017
- New ASHRAE Website: Launching February 2018
- New Standard 90.1 Portal: Launched January 2018
- ASHRAE Leadership Academy: May 18-19, 2018, Atlanta, GA
  - Rising chapter leaders network & learn best practices
- Global Giveback: April 22-28, 2018
  - Service-oriented sustainability events during a one-week period to generate excitement at the local level and increase chapter visibility



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## Presidential Ad Hocs Ethics Enforcement Procedures Task Group

Ethics Enforcement Procedures Task Group will review and recommend changes to ROB 3.980 Enforcement Procedures for Violation of the ASHRAE Code of Ethics. In addition, the Task Group will address procedures for Ethics allegations against Officers and/or BOD members. The Task Group may also consider making the review investigation more independent from ASHRAE leadership.

Task Group Meeting: During the Winter Conference



## Presidential Ad Hocs Regional Staff Support Analysis Task Group

The Regional Staff Support Analysis Task Group is to study the placement of hired representatives (regional staff) in ASHRAE Regions to support volunteer programs, with particular focus on advocacy.

Preliminary Report to the Board: During the Winter Conference



## Nomination Process Ad Hoc

The purpose of the Nomination Process Ad Hoc is to:

- Reviews all documents of the Nominating Committee including the By-laws, Board-Approved Rule's and Nominating Committee Manual of Procedure and reference manual for current relevance.
- Review election procedures of similar organizations (ASME, ASHE, etc.).
- Determine if one nominee per office on the member ballot is appropriate.
- Determine if we should consider cancelling the tenet of "the job seeks the person, the person does not seek the job."
- Determine if the balance of at-large and regional members of the Nominating Committee is optimal.

Final Report Due: April 2018



## Global Training Center for Building Excellence -Dubai

- Opened: September 2017
- Purpose: To provide relevant self-supporting training to members and nonmembers in the Middle East and North Africa (MENA) and chapters in the Region at Large.
- Regional instructors and courses modified for the region
- Recognition: Individuals attending 42 hours of instruction and passing a course exam may earn the *ASHRAE Building Excellence Credential MENA*.



## Global Training Center for Building Excellence -Dubai

Three courses have been held in Dubai:

- HVAC Design Training (twice)
- VRF Applications

GTC is reaching out to chapters in the RAL to schedule instructors from local engineering societies and universities including:

- Saudi Council of Engineers (SCE)
- Bahrain Society of Engineers (BSE)
- The British University in Egypt (BUE)
- Egyptian Engineers Syndicate (EES)



## YEA

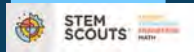


- Members Council and the ASHRAE Board approved the Young Engineers in ASHRAE (YEA) Committee transition to a grassroots committee, effective July 1, 2018
- Change: YEA RVCs will now be nominated through each Region's CRC nomination caucus
- Change: YEA Chapter Chair position will become a required chapter position that receives transportation reimbursement to CRC.



## STEM Scouts

- Sub-committee members will reach out to one chapter SAC chair in their area responsible for one of the eight STEM Scout groups that were provided as stronger groups.
- Goal: To have the chapter SAC chair and STEM Scouts liaison pilot a partnership.
- Pilot Goal: 3 to 5 chapters involved in pilot
- Timeline: 2 months to reach out for partnership and report



## 2019-2024 Strategic Plan

### Timeline

- November 2017 - December 2017: Select Strategic Plan consultant & negotiate contract  
**Complete - McKinley Advisors**
- January 2018: Consultant presentation to BOD at ASHRAE Winter Meeting
- March 2018: Board strategic planning session
- June 2018: Board reviews first draft of Strategic Plan
- November 2018: Board reviews and approves revised draft of Strategic Plan
- December 2018 - March 2019: Stakeholder review of and feedback on revised draft of Strategic Plan
- June 2019: BOD approve Strategic Plan 2019-24 at ASHRAE Annual Meeting
- July 2019 - June 2024: Plan is implemented, tracked, and updated as necessary with status reported to the membership with Dashboard



## Recent Publications and Standards

- ASHRAE Design Guide for Dedicated Outdoor Air Systems ASHRAE GreenGuide: Design, Construction, and Operation of Sustainable Buildings, 5<sup>th</sup> Edition
- ASHRAE Pocket Guide for Air Conditioning, Heating, Ventilation, Refrigeration, 9<sup>th</sup> Edition
- ASHRAE Design Guide for Cleanrooms: Fundamentals, Systems, and Performance
- ASHRAE Design Guide for Air Terminal Units: Selection, Application, Control, and Commissioning
- IT Equipment Power Trends, 3<sup>rd</sup> Edition
- Fundamentals of Design and Control of Central Chilled-Water Plants
- Standard 90.1 Users Manual (both the printed book and online with an online version of the standard and redline)
- Standard 170-2017: Ventilation of Health Care Facilities Principles of HVAC



## Join Us

- ACREX India 2018, Bangalore, India, February 22-24
- Canadian Mechanical & Plumbing Exposition, Toronto, Canada, March 21-23
- USA Science & Engineering Festival Expo, Washington, D.C., April 7 & 8
- CHR 2018 – China Refrigeration 2018, Beijing, China, April 9-11
- ASHRAE Webcast, Making Energy Efficiency a Reality, April 19
- 2018 ASHRAE Annual Conference, Houston, TX, June 23-27
- ASHRAE 2017 Building Performance Analysis Conference, Chicago, IL, September 26-28
- AHR Expo Mexico, Mexico City, Mexico, October 2-4
- Third International Conference on Efficient Building Design, Beirut, Lebanon, October 4-5
- Chillventa 2018, Nurnberg, Germany, October 16-18
- Greenbuild 2018, Chicago, IL, November 14-15





### ASHRAE – UNEP Cooperation; Background

1. Cooperation agreement signed in 2007
2. Why ASHRAE; ability to bring key industry experts under one roof, global confidence and acceptance for ASHRAE references plus ASHRAE presence in different countries regions (
3. Biennial work-plans established since 2009, **recent one for 2017-2018 launched in Jan-2017**
4. Many joint events and session organized jointly with ASHRAE
5. Liaison Committee established to ensure timely implementation and follow-up on the work plans and activities.

### Why ASHRAE & UN Environment OzoneAction ?

1. Strategic and geographical presence
2. Together means combined access to governments and industry

9 Regional Networks of National Ozone Officers  
147 developing countries

180 Chapters & 55,000+ members in 139 countries

Main theme of 2017-2018 Work Plan

### Working Beyond High-GWP Refrigerants

Main Goals	Actions
<b>Advocacy and Knowledge Sharing</b>	<ul style="list-style-type: none"> <li>• Global Conferences and Events</li> <li>• Refrigerants Awareness Package</li> <li>• Low- GWP Innovation Award Program</li> </ul>
<b>Training, Education and Practice</b>	<ul style="list-style-type: none"> <li>• Online Training Program on Refrigerants</li> <li>• Contemporary Learning Tools for Universities</li> <li>• Assessment Program for RAC Plants</li> </ul>

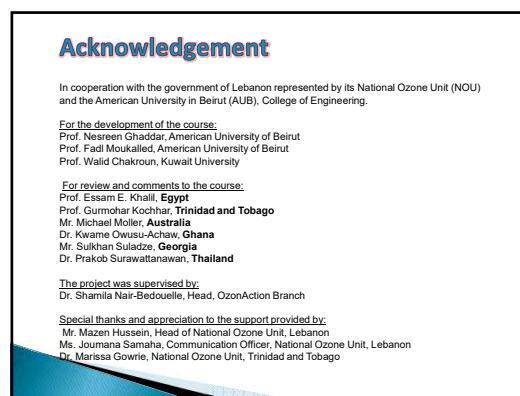
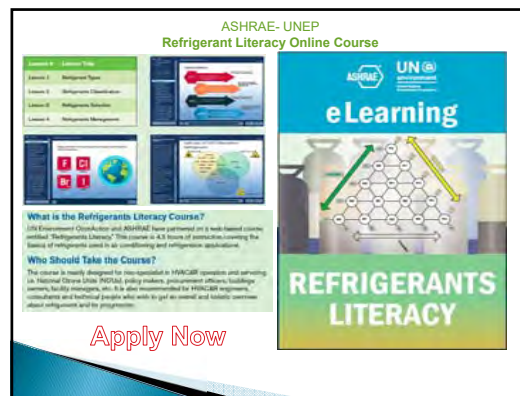
### Under the new work plan; Quick and Visible delivery

**Example from 2017 only...**

- **Cooperation at three international conferences:**
  - Sustainable RAC Technologies for Marine & Fisheries Sectors (Bangkok)
  - District Energy for Urban Development (Sharm El-Sheikh)
  - Developing Economies (Delhi)
- **Two Online Courses**
  - Refrigerants Literacy ( launched at OEWG-2017)
  - 2<sup>nd</sup> Course will be presented at MOP and launched early 2018
- **Two International programs initiated**
  - Sustainable O&M for RAC Installations
  - Global campaign to promote UN Environment University Course

### Example from the cooperation in conferences and events

1. International Conference on Sustainable Technologies of RAC in Marine/Off-Shore Fisheries Sectors, **Bangkok- Thailand (April 2017)**
2. International Conference on District Cooling for Urban Development, **Sharm Al-Sheikh, Egypt (Sept 2017)**
3. ASHRAE Developing Economies Conference, **Delhi, India (Nov 2017)**
4. Sixth International High Ambient Symposium, **Dubai, UAE ( late 2018)**







## FREE REFRIGERANTS COURSE



### Seeking Instructors to Lead Refrigeration Management Course

ASHRAE has been chosen to distribute a university-level course developed by UN Environment on Refrigerant Management for engineering students.

ASHRAE is seeking instructors willing to place the course in their curricula. Instructors will be provided all with lecture notes, activity plans, and course presentations. There is no need to develop the course.

Over the last two decades UN Environment has been involved in training programs offered to civil engineers and service technicians on environmentally sound practices including alternatives reduction with a focus on ozone and pollutants.

The new course is part of its goal to help compressors, account, information at the classroom level. Future engineers will be offered the skills required to manage refrigerants responsibly in aerial, technical and policy aspects associated with the refrigeration and air-conditioning industry.

UN Environment is originally involved in identifying instructors to adopt the course.




#### Course Outline

- LESSON 1 - INTRODUCTION TO REFRIGERATION AND AIR-CONDITIONING SYSTEMS
- LESSON 2 - REFRIGERANT MANAGEMENT
- LESSON 3 - OZONE
- LESSON 4 - REFRIGERANT MANAGEMENT: DEVELOPMENT OF DESIGN & REGULATIONS
- LESSON 5 - HFCs
- LESSON 6 - REFRIGERANT MANAGEMENT: DEVELOPMENT OF DESIGN & REGULATIONS
- LESSON 7 - HFCs
- LESSON 8 - REFRIGERANT MANAGEMENT: DEVELOPMENT OF DESIGN & REGULATIONS
- LESSON 9 - HFCs
- LESSON 10 - REFRIGERANT MANAGEMENT: DEVELOPMENT OF DESIGN & REGULATIONS



ASHRAE is seeking instructors willing to place the course in their curricula. Instructors will be provided all with lecture notes, activity plans, and course presentations. There is no need to develop the course.

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ASHRAE

UNEP/ASHRAE Assessment Program:  
Sustainable Operation and Maintenance  
of Air Conditioning and Refrigeration  
Plants

Bill McQuade, P.E., ASHRAE Fellow  
January 21<sup>st</sup>, 2018  
Chicago,

## Overview of the Project

- This ambitious project would entail the compilation of best practices related to the following areas related to the operation and management of air-conditioning and refrigeration systems/plants:
  - Safe storage and proper handling of refrigerants
  - Periodic leak checking and proper documentation
  - Checklist for maintaining equipment to extend life and maintain energy efficiency
  - Fault detection and preventative maintenance
  - Proper commissioning and recommissioning practices to optimize system performance
  - Minimum required servicing equipment and tools
  - Proper disposal of equipment and reclamation of refrigerant at end of product life.
  - Competencies of personnel/companies responsible of operating and/or maintaining the refrigeration and air-conditioning plants
- As with any project with UNEP the resulting guideline will be provided free of charge to the intended users.





## Summary of Project:

- One of the main elements of the UNEP/ASHRAE Biennium joint Work Plan of 2017-2018 is to develop an assessment program for the sustainable operation and maintenance of refrigeration and air-conditioning plants.
- This ambitious project would entail the develop a comprehensive guide of "best practices" related to the operation and management of air-conditioning and refrigeration systems/plants.

The work is being completed in 4 separate stages over approximately 18 months with formal approval "gates" at the end of each stage:

- Stage I: Specification and Business Case Development
- Stage II: Development of technical modules with resulting checklists and procedures
- Stage III: Formal review and pilot of the program
- Stage IV: Launch and Outreach

Focus of current Ad Hoc





## Next Steps

- Revision of scoping document based on feedback.
- Final approval of the document in February
- Identify members of the Stage II Ad hoc.
- Secure funding and identify contractor to complete the work.
- Identify members of the Project Monitoring MTG
- Determine pilot locations and review/revise program materials based on results and feedback.
- Joint UNEP/ASHRAE Launch of the program.



## Viable Business Cases: A Key to Success

Two important business cases that must be developed:

1. End User
  1. Providing value to the end user is critical for adoption. This program is targeted for use in developing countries where expertise and technical training of maintenance managers and service technicians are limited. They must see value in the program or they will not adopt it.
2. ASHRAE
  1. The guideline is provided for free to the end user. However, ASHRAE must be able to generate enough revenue from the sale of standards, guidelines, training courses, etc. to pay for the development and maintenance of the program.



## Stage I: Ad Hoc Members

- Ayman El-Talouny (ASHRAE Member, UNEP)
- William Walter (ASHRAE Board Member, Expert on Safety Codes)
- John Vucci (ASHRAE Member, University of Maryland Physical Plant)
- Barbara Minor (ASHRAE Member, Refrigerant Expert, Member of the Low GWP MTG)
- Robert Bates (ASHRAE Member, Expert on Sustainable Operation)
- Robert Rooley (Presidential Member, Expert on Reliability and Maintenance Practices)
- Prof. R. S. Agarwal (ASHRAE Member, Expert on Refrigeration and AC Design, India)
- Pro. Essam E. Khalil (ASHRAE Member, Expert on Refrigeration and AC Design, Middle East)
- Bill McQuade (ASHRAE Board Member, Refrigerant Regulation Chiller Design)



## Celebrating 10 Years of Partnership

### Award for Climate Protection through Innovation in Refrigerant Management

W. Stephen Comstock, Director, Publishing/Education, ASHRAE

29th MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL  
(MOP-29)

## Innovation in Refrigerant Management

- **INNOVATION** – UN Environment and ASHRAE developing an international award for innovative design, research or practice of lower-GWP technologies for refrigeration and air-conditioning applications in developing countries.
- **AWARENESS** – Purpose is to increase awareness of how sound refrigerant practices contributes to mitigation of climate change through recognition of individuals who design and/or conceive innovative technologies in refrigeration management.
- **COMMUNICATION** – Important output is communication of innovation techniques through ASHRAE publishing vehicles and chapter/member network so the innovation can be adopted industry wide.



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## Aware Parameters

- Two categories:
  - Residential Applications
  - Commercial/Industrial Facilities
- In each category, a first place winner will be awarded and honorable citation for other deserving applicants at the discretion of the Jury.
- Winners selected for innovative solutions through designs, practice or research using lower-GWP technologies and taking into consideration:
  1. Extent of need;
  2. Innovative aspects in transforming conventional practices;
  3. Replication that can be achieved in developing countries;
  4. Economy feasibility to developing countries



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### Submission Process

- Open online to individuals, institutions, organizations, firms.
- The submission form will require descriptive responses to each of the following questions:
  - Project/Applicant details
  - Description and goal of the research, design, practice or project
  - Environmental impact achieved
  - Description of innovation
  - Further application of project
  - Financial feasibility and economic impact



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### Recognition & Communication of Innovation

- Award ceremony at an UN Environment event chosen by UN Environment.
- ASHRAE will work with the winners to prepare individual displays with information about each winning project at the respective UN event.
- Display organized at an ASHRAE event following the UNEP recognition to also acknowledge the winners and allow for dissemination of information to the ASHRAE network.



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Thank you



# COLD CHAIN TECHNOLOGY BRIEF

## COLD STORAGE AND REFRIGERATED WAREHOUSE



*Acknowledgment: This Cold Chain Brief was prepared by Judith Evans (IIR C2 Commission President), has been reviewed by Jim Curlin and Ezra Clark experts from the UN Environment OzonAction and also several experts from the IIR commissions.*

# IIR-UN Environment Cold Chain Brief on Cold Storage and Refrigerated Warehouse



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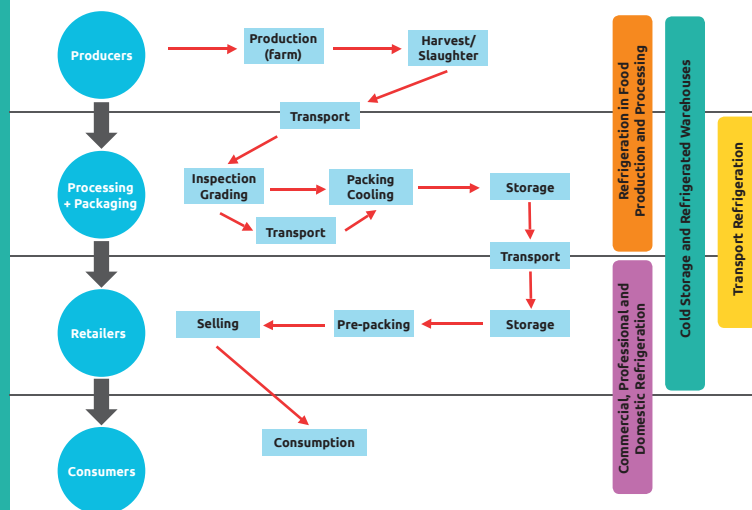
# 2 The Cold Chain

## Summary

Cold storage warehouses store food after production and before foods are transported and distributed to supermarkets or catering establishments. Food is stored either chilled or frozen and may remain in the store for periods of a few hours, days or even a year (for some fruits and vegetables) in chillers and up to several months in freezers. This sector has been shown to be one of the sectors of the cold chain where the temperature of products is well temperature-controlled. Energy usage is important to cold store operators as it is a high proportion of the overall operating costs. Cold storage warehouses traditionally have high usage of low global warming potential refrigerants.

The “cold chain” refers to the various stages that a refrigerated product passes through, either until it is removed by a customer in a retail environment or unloaded from a delivery vehicle a few metres from its destination. From the moment a fruit or vegetable is harvested or an animal is slaughtered, the product starts to deteriorate. The deterioration of a product can be slowed by reducing the temperature at which it is stored. In fruits and vegetables, this slows down metabolic processes, which, in turn, slows spoilage. Reduced temperatures slow the growth of potentially harmful bacteria in animal products that are stored at frozen temperatures, allowing them to be shipped all over the world with minimal food safety risks. It is important that suitable temperature control be maintained from as soon as is feasible to as close as possible to consumption. From the raw materials stage to the various distribution storage facilities a commodity passes through, transport refrigeration keeps it at the temperature required to maximise storage life and quality for many days, weeks and months between cold storage facilities.

**The Cold Chain**



©Diagram : Judith Evans and IIR

**Fig.1**

The cold chain is often quite complex, with foods being chilled or frozen on more than one occasion. Worldwide about 400 million tonnes of food are preserved using refrigeration. The overall volume of cold stores (refrigerated warehouses) around the globe is about 600 million m<sup>3</sup>. The IIR estimates that the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion, including 1.5 billion of domestic refrigerators. 90 million of commercial refrigerated equipment (including condensing units, stand-alone equipment and centralized systems) are operating in the world. There are also 4 million refrigerated road vehicles (vans, trucks, semi-trailers or trailers), 1.2 million refrigerated containers (reefers) and 477,000 supermarkets, with a footprint ranging from 500 to 20,000 m<sup>2</sup> in operation and where 45% of the electricity consumed is used by refrigeration equipment (IIR, 2015<sup>2</sup>).

<sup>2</sup>IIR, 2015. 29<sup>th</sup> Note: The Role of Refrigeration in the Global Economy.

**I Fig.1: Overall cold chain with the different components**

## 1 Introduction

Once food is brought to the desired temperature after primary and secondary processing (food chilling/freezing or processing into a secondary product such as a meal), the storage and distribution stages of the cold chain should maintain food at a constant temperature. However, this is not always the case as food is often chilled or frozen in the storage chamber rather than being chilled or frozen in a dedicated blast chiller/freezer. Cold storage warehouses are usually considered within the industrial refrigeration sector. Such systems have heat extraction rates of up to 10 MW and generally operate as chillers or freezers. Generally most freezers operate between -22 and -26°C, although there are exceptions such as speciality ice cream freezers and niche products such as sushi which may be stored at -60°C. Food may be stored in freezers for several months. Storage times in chillers can vary considerably from a few hours or days to up to a year for certain fruits and vegetables. Chillers typically operate between -1 and 4°C, with some fruit, bakery and vegetable products being stored at between 8 and 12°C (UNEP, 2014<sup>1</sup>).

<sup>1</sup>UNEP, 2014. Montreal Protocol on Substances that deplete the ozone layer. 2014 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, 2014 assessment.



# 3 Overview of Cold Storage and Refrigerated Warehouses

All chilled and frozen are stored in a cold store at least once during their journey from production to the consumer. Chilled stores generally maintain products at temperatures between -1 and 12°C whereas frozen stores generally maintain products at temperatures below -18°C. The cold store market is extremely diverse consisting of small stores with volumes of 10-20 m<sup>3</sup> up to large warehouses with hundreds of thousands of cubic meters (Figure 2). All cold stores have the function of storing a product at the correct temperature and to prevent quality loss as economically as possible.



Fig.2

In chilled storage rooms temperature control is a food safety issue where increases in temperature may be detrimental to the safety and shelf life of the food. In frozen store rooms food safety is not an issue; assuming that the temperature in the room is maintained below -10°C, which is the temperature that is generally accepted as the minimum temperature for microbe growth. Food quality changes can however occur as in most instances food is stored above its glass transition temperature (temperature at which no further water can be frozen). For most food the glass transition temperature is below -30°C and most frozen storage facilities will operate at between -18 and -22°C (Nesvadba, 2007<sup>3</sup>). Temperatures in storage warehouses have been shown by Derens et al. (2007<sup>4</sup>) to be better controlled than any other sector of the cold chain (Figure 3).

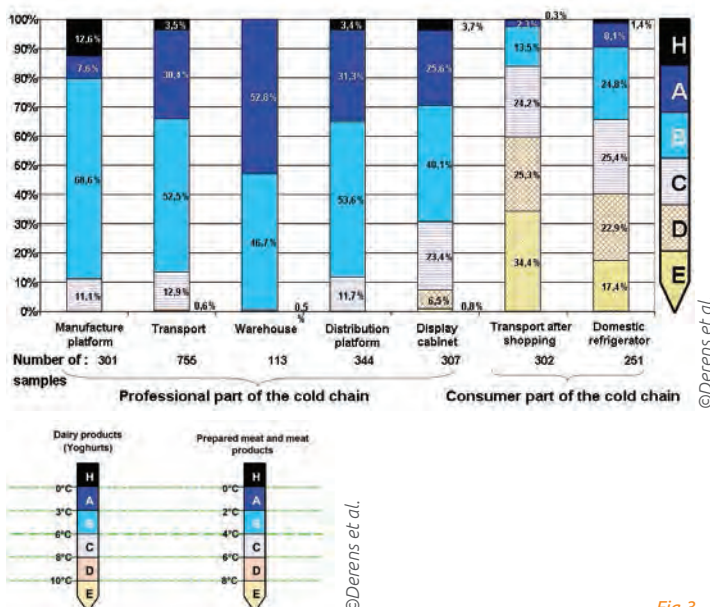


Fig.3

# 4 Current Issues and Market Trends

In cold stores reducing cost is a large driver. This can be achieved through reducing energy usage (and consequently indirect emissions) or by operating the store at times of lower energy tariffs (often termed 'load shifting'). The design of the store and how it is used are vitally important aspects of minimising energy use. Cold stores also contribute to direct emissions through loss of refrigerants and as such, the use of environmentally friendly low global warming potential (GWP) refrigerants is a significant issue in the current market.

## 4.1. Indirect emissions

Indirect emissions are affected by the cooling load, fuel mix of electricity generation, and efficiency of the plant. The heat loads on the room are dominated by transmission (through the walls and ceiling), infiltration through doors, fixed loads such as fans, floor heating (if relevant) and defrosts and heat loads from people and machinery (Figure 4).

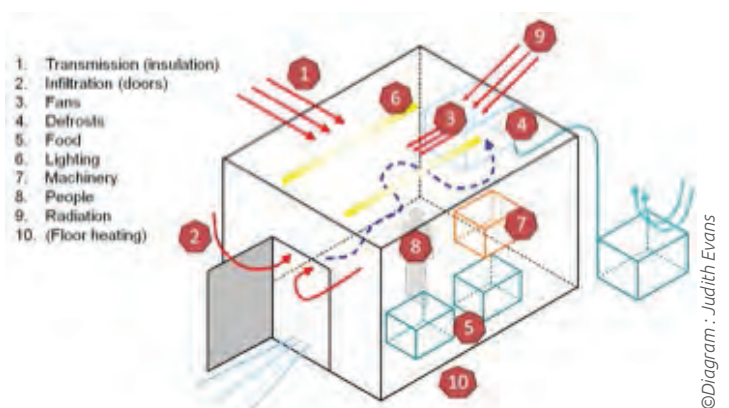
Ideally the plant should be designed for maximum efficiency at the most common conditions. This requires knowledge of local seasonal ambient conditions (temperature and humidity) to define condensing temperatures (the refrigeration system condenser is generally located outside the building) and of usage patterns and heat loads on the store.

Cold storage rooms consume considerable amounts of energy. Within cold storage facilities 60-70% of the electrical energy can be used for refrigeration. In 2002 the IIR estimated that cold stores used between 30 and 50 kWh.m<sup>-3</sup>.year<sup>-1</sup> (Duiven and Binard, 2002<sup>5</sup>). More recent surveys carried out on a small number of cold stores have shown that energy consumption can dramatically exceed this figure, often by more than double (Evans and Gigiel, 2007, 2010<sup>6</sup>). These surveys also demonstrated that energy savings of 30-40%

<sup>3</sup>Nesvadba, P, 2007. Thermal properties and ice crystal development in frozen foods. In Frozen Food Science and Technology, edited by Evans, J.A. Blackwell Publishing.

<sup>4</sup>Derens, E., Palagol, B., Cornu, M., Guilpart J., 2007. The food cold chain in France and its impact of food safety. IIR ICR2007, Beijing, China.

<sup>5</sup>Duiven, JE., Binard, P., 2002. Refrigerated storage: new developments. Bulletin of the IIR, No. 2002-2.



©Diagram: Judith Evans

Fig.4

Fig.2: Typical cold stores: small (left), large (right)  
Fig. 3: Temperatures throughout the French cold chain  
Fig. 4: Heat loads in a refrigerated warehouse.

were achievable by optimising usage of the stores, repairing current equipment and by retrofitting of energy efficient equipment. However, cold store operators are often reluctant to install new equipment without sufficient information on savings that could be achieved.

There are few published surveys comparing the performance of considerable numbers of cold stores. Evans et al. (2015<sup>7</sup>) compiled data from 429 cold stores (167 chilled stores, 187 frozen stores and 75 mixed stores). The data collected covered 23 countries. Results from the survey are in Table 1. The survey demonstrates that considerable differences exist in energy consumption between cold stores. In many cases the best store could consume half the energy per cubic meter (also termed specific energy consumption, SEC) of the worst store. There may be many reasons for this that are not just due to poor efficiency. For example the store with the higher SEC may have higher usage and a different function than the store with the lower SEC.

## 4.2. Direct emissions

The scale of refrigerant leakage varies considerably between different refrigeration equipment types and from country to country. The leakage rates shown in Table 2, which are believed to be typical for the EU-15 region, are based on the UK Greenhouse Gas Inventory for 2007 (Defra, 2010<sup>8</sup>) and indicate significant variation between different types of equipment. Industrial refrigeration (that includes cold storage) had refrigerant leakage of 8% per year. Data on refrigerant emissions in developing countries is scarce but data from Giz (2017<sup>9</sup>) would indicate that refrigerant emissions can be about twice as high in developing countries as in industrialised countries.

**Table 1: Range in SEC values for cold stores examined (Evans et al., 2015<sup>7</sup>).**

		Chilled (kWh.m <sup>-3</sup> .year <sup>-1</sup> )	Frozen and Mixed (kWh.m <sup>-3</sup> .year <sup>-1</sup> )
All stores	Number of cold stores	167	262
	Mean	55.7	71.5
	Minimum	4.4	6.0
	Maximum	250.4	391.6
	Standard deviation	34.7	40.6

<sup>6</sup>Evans, J.A., Giegel, A., 2010. Reducing energy consumption in cold storage rooms. IIR ICC2010, Cambridge, UK.

<sup>7</sup>Evans, J., Foster A., Huet, JM., Reinholdt, L., Fikiin, K., Zilio, C., Houska, M., Landfeld A., Bond, C., Scheurs, M., Van Sambeek, T., 2015. Specific energy consumption values for various refrigerated food cold stores. IIR ICR2015, Yokohama, Japan.

<sup>8</sup>Defra, 2010. 2010 Guidelines to Defra / DECC's GHG conversion factors for company reporting: methodology paper for emission factors.

<sup>9</sup>Giz. 2017. <http://www.green-cooling-initiative.org/technology/chillers/green-cooling-potential/>.

**Table 2: Typical refrigerant emissions by RAC sector (Defra, 2007<sup>8</sup>).**

Type of Equipment	Typical Range in Charge Capacity (kg)	Installation Emission Factor (% of initial charge)	Operating Emissions (% of initial charge/year)	Refrigerant remaining at disposal (% of initial charge)	Refrigerant recovered (% of remaining charge)
Domestic Refrigeration	0.05 - 0.5	1.0%	0.3%	80%	99.0%
Stand-alone Commercial Applications	0.2 - 6	1.5%	2.0%	80%	94.5%
Medium & Large Commercial Applications	50 - 2,000	2.0%	11.0%	100%	95.0%
Transport Refrigeration	3 - 8	1.0%	8.0%	50%	94.0%
Industrial Refrigeration (inc. food processing and cold storage)	10 - 10,000	1.0%	8.0%	100%	95.0%
Chillers	10 - 2,000	1.0%	3.0%	100%	95.0%
Residential and Commercial A/C including Heat Pumps	0.5 - 100	1.0%	8.5%	80%	95.0%
Mobile Air Conditioning	0.5 - 1.5	1.0%	7.5%	50%	88.0%

# 5 Current Refrigerants Used and Potential Alternatives

Refrigerant selection is an important issue in terms of environment, safety and sustainability. Within the food industry the majority of chilled/frozen stores use direct expansion refrigeration systems. Direct expansion systems consist of two heat exchangers (a condenser and an evaporator), a means to pump and raise the pressure of the refrigerant (compressor) and an expansion device plus associated control devices, storage vessels and safety devices. In larger plants pumped recirculation systems are common, often operating using ammonia (R717). In this system the refrigerant is contained in a large vessel termed a 'surge drum' and is pumped or fed by gravity to the evaporator(s).

Currently a large number of cold stores operate using ammonia as a refrigerant which has negligible GWP but is mildly flammable and toxic. To ensure safe operation it is vital that safety training and safe practices are applied when using a refrigerant such as ammonia. Training is seen as a key issue to facilitate transitions to low-GWP refrigerants where flammability and toxicity are issues that need to be dealt with. Often cost is the major consideration and there needs to be a move to lifetime costs which often favour systems that may have higher initial and maintenance costs but have lower energy costs.

In some instances cascade systems may be employed. The most common CO<sub>2</sub> cascade system incorporates CO<sub>2</sub> on the low temperature side operating below its critical temperature and ammonia on the high temperature side. This design can provide low temperature heating of hot water but is not suited for high temperature heating.

According to UNEP (2017<sup>10</sup>) industrial refrigeration accounts for approximately 2% of HFC consumption (in terms of CO<sub>2</sub>-eq) and is projected to grow by approximately 6.7% annually between 2015 and 2050. There is an apparent move from ammonia to HFC refrigerants, especially in countries where there have been accidents or concern about safety (this is especially the case in Article 5 countries). Safety standards do exist through local regulation and ISO (International Organisation for Standardisation), IEC (I – E – C) and regional (such as European Norm, EN) standards. For industrial systems, ISO 5149 (2014) and EN 378 (2008/2012) cover design, construction and safety.

Smaller cold stores often operate on HCFC or HFC refrigerants and some newer stores operate on natural refrigerants (primarily CO<sub>2</sub>, R744). In addition, although a relatively small proportion of the market, stores may operate on a secondary refrigerant (e.g. water, brine, glycols, silicon oils, or Flo-ice™) that is cooled by a primary centralised refrigeration system and then pumped to the cold store to extract heat. The advantage of such systems is that a flammable or toxic refrigerant can be used in the primary circuit which is isolated from the cooling process (therefore aiding safety) and the charge of the refrigerant in the primary circuit can be minimised.

Combined heat and power, polygeneration and trigeneration technologies where multiple energy inputs may be used to provide multiple energy outputs have potential to reduce energy consumption if the outputs can be put to use. The primary energy for such systems can include fossil fuels, biofuels and renewable energy and the energy outputs include heat, power and cooling. For traditional cold stores where refrigerated storage is the only function there may be little use for the outputs, although cold stores are often co-located or close to other production facilities which could benefit from the outputs.

Very occasionally absorption systems can be used in cold stores if excess heat is available to drive the system. Absorption systems vary the boiling point of a refrigerant by combining it with another fluid. For freezing this is usually ammonia-water. In the future greater use of heat reclaim may be justified and the use of energy grids and district thermal systems may be attractive and economic.

Although a number of novel refrigeration technologies are being developed (e.g. magnetocaloric, thermoelectric, thermoacoustic) these have limited apparent opportunities for cold stores. Most of these new technologies have been aimed at smaller refrigeration systems in the commercial and domestic markets.

**Table 3: Summary of current and alternatives refrigerants**

Cold Storage and Refrigerated Warehouses		
Size of store	Current higher GWP refrigerants (GWP kg-CO <sub>2</sub> )	Alternative lower GWP refrigerants (GWP kg-CO <sub>2</sub> )
<b>Small store: less than 100 m<sup>3</sup></b>	HFC-134a (1360), HFC-404A (4200) HCFC-22 (1810), HFC-410A (1920), HFC-407C (1920), HFC-507A (3990), HFC-422D (2470)	Wide range of HFO and HFO blend refrigerants, HC-290 (5), HC-1270 (1.8)
<b>Large store: Larger than 100 m<sup>3</sup></b>		Primary: R-744 (1), R-717 (0) Secondary: Brine, glycols, silicon oils

<sup>10</sup> UNEP, 2017. *Montreal Protocol on Substances that deplete the ozone layer. UNEP, Report of the Technology and Economic Assessment Panel.*



# 6 Development Perspectives and Challenges

There are many ways of operating or controlling food refrigeration that will save energy. Many cold store operators utilise control strategies to save energy. This can involve control of evaporator fans, the refrigeration system or of the temperature inside the cold room.

Reduction of energy consumption by cold stores should focus on three principal areas:

- Reducing heat loads on the store.
- Improved maintenance and usage operations.
- Improved operation/efficiency of the refrigeration system.

Any increase in the refrigeration system cooling temperature (evaporating temperature) or reduction in the heat rejection temperature (condensing temperature) will save energy. In many instances (especially in frozen stores) temperatures are kept lower than necessary to provide a safety margin in case of plant failure.

Often operators apply strategies to save money (not necessarily energy) by switching off the refrigeration systems during peak demand energy periods when energy is more expensive (energy can be 4 times more expensive at peak grid demand than at low demand times). During this period the temperature within the room is allowed to slowly increase and is then reduced once the cost of the energy returns to a lower level.

In the future the use of renewable energy sources such as wind, wave and solar are likely to play a role in reducing the environmental impact of the energy used by cold stores.

## 6.1. Technical challenges and potential

Energy is a major cost in the operation of food cold stores. Work from a number of energy audits has shown that considerable energy savings can be achieved in cold stores. In work carried out by Evans et al. (2014<sup>11</sup>) reductions in energy consumption were identified by optimising usage of stores, repairing current equipment and by retrofitting of energy efficient equipment. Often these improvements had short payback times of less than 1 year.

Considerable work has been carried out in the UK and now extended to Europe to reduce refrigerant leakage (Cowan et al., 2010<sup>12</sup> and 2011<sup>13</sup>). Legislation, fiscal measures, new technologies, alternative refrigerants and other initiatives have all helped to drive significant improvements in refrigerant leakage. The European F-Gas Regulation (regulation 842/2006) ensures that installation, maintenance, service, (de)commissioning and disassembly of refrigeration systems containing or designed to contain HFCs can only be done by duly certified professionals. The Regulation requires regular leak checking by appropriately trained personnel. All of these obligations have been applicable since July 2009.

The implication of the F-Gas Regulations is a move to low GWP refrigerants. Ammonia is a widely used low GWP refrigerant in cold stores but requires high safety standards and refrigeration technicians to be fully trained. Many alternative low GWP refrigerants have issues related to high pressure or flammability. There are therefore increased issues surrounding safety and

training of refrigeration technicians to ensure that systems are applied and installed safely.

Use of heat reclaim in cold stores and greater integration between the store and 'local' amenities may become more economic in the future. Relatively low-grade heat can be reclaimed from the oil coolers of compressors and up to 60% of the compressor motor power can be absorbed in the oil. Systems have been developed that use heat from the compressor discharge or compressor oil coolers to pre-heat water in a boiler.

## 6.2. Related driving policies

Refrigeration and Air Conditioning Industry witnessed considerable development and modernization in the last 3 decades partly as result to the international environmental policies where many refrigerants that have been used efficiently for decades, are held responsible to the Ozone Layer Depletion as well as Global Warming. The phase-out of ozone depleting substances (ODSs), under the Montreal Protocol, triggered significant changes in the industry moving towards alternative refrigerants and technologies that has zero-ODP (Ozone Depletion Potential).

In October 2016, the Kigali Amendment to the Montreal Protocol brought another dimension to the mandate of the Montreal Protocol by adding the control of production and consumption of hydrofluorocarbons (HFCs) under its mandate which will have major contribution towards the fight against climate change. Control of HFCs production and consumption will add to the climate benefits already achieved by the Montreal Protocol through the phase-out of ODSs including CFCs and HCFCs. The emissions of HFCs are also listed within the group of GHGs (Greenhouse Gases) under the Climate related conventions i.e. Paris Agreement and previously the Kyoto Protocol. However, actions to specifically control HFCs emissions within the climate regime are not yet set except for reporting requirements under the UNFCCC (UN Framework Convention on Climate Change).

The refrigerant climate impact of refrigeration equipment depends on direct and indirect effects. The direct effect is from its GWP (Global Warming Potential) and amount of a refrigerant emitted to the atmosphere (either from a leak, accident, or from improper handling or disposal). The indirect effect is associated with the energy consumed during the operation of equipment which, over its lifetime, occurs as a result of the CO<sub>2</sub> (CH<sub>4</sub> to lesser extend) produced by fossil fuel power plants, and is commonly greater than the direct effect. Minimizing direct and indirect impacts, of all types of refrigerants, emissions should be addressed through improved design, better field commissioning and maintenance practices, sound decommissioning procedures and enforcement to local relevant standards and regulations.

<sup>11</sup> Evans, J.A., Hammond, E.C., Gígiel, A.J., Foster, A.M., Reinholdt, L., Fikiin, K., Zilio, C., 2014. Assessment of methods to reduce the energy consumption of food cold stores. *Applied Thermal Engineering* 62 (2014) 697-705.

<sup>12</sup> Cowan, D., Gartshore, J., Chaer, I., Francis, C., Maidment, G., 2010. REAL Zero – reducing refrigerant emissions & leakage - feedback from the IOR project, *Proceedings of the Institute of Refrigeration*, Proc. Inst. R. 2009-10. 7-1.

<sup>13</sup> Cowan, D., Beermann, K., Chaer, I., Gontarz, G., Kaar, K., Koronaki, I., Maidment, G., Reulens, W., 2011. Improving F-Gas containment in the EU – results from the Real Skills Europe Project. IIR ICR2011, Prague, Czech Republic.

## 6 Development Perspectives and Challenges

There are several principal organisations developing standards related to the refrigeration and air-conditioning sector. The UNEP International Standards in Refrigeration and Air-Conditioning booklet (UNEP, 2014<sup>14</sup>) summarises the main international standardisation organisations and provides some examples of national and regional standards organisations.

The cold chain sector is one of the most important but overlooked business segments in terms of being addressed in a holistic approach. This is because it crosscuts with different economic, social and technical areas i.e. food industry, health, refrigeration, transportation, tourism, etc. The norms and directions for cold chain technology selection that has less environmental impact, energy efficient operation and affordable economics is scattered amongst different groups and entities within the same country. In September 2015, International Community adopted the 2030 Sustainable Development Goals (SDGs) stipulating Goal #2 «Zero Hunger» as the second global goal which needs to be achieved by 2030. This automatically means the urgent need to efficiently manage the portfolios of «Food Security» & «Food Waste» which depends on the cold chain capabilities. While this goal can be noted as the main goal with direct relation to cold chain, other goals are also connected to the cold chain business i.e. Goal #3: Health and Wellbeing, Goal # 9: Industry Innovation and Infrastructure, Goal # 12 Responsible Consumption and Production as well as Goal #13: Climate Action. Therefore, the integrated approach in addressing the cold chain challenges can lead to multi socioeconomic and environment benefits.

## Conclusions

The cold storage sector is generally considered to be one of the best temperature controlled sectors of the food cold chain. The majority of stores use refrigerants with a low GWP and so the major source of emissions is from energy use. Energy usage in cold stores has been shown to vary considerably and many stores could reduce their energy consumption by applying good practice or efficient equipment and components.

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<sup>14</sup> UNEP, 2014. *International Standards in Refrigeration and Air-Conditioning. An introduction to their role in the context of the HCFC phase-out in developing countries.*



# COLD CHAIN TECHNOLOGY BRIEF

COMMERCIAL,  
PROFESSIONAL AND  
DOMESTIC REFRIGERATION



*Acknowledgement: This Cold Chain Brief was prepared by Judith Evans (IIR C2 Commission President), has been reviewed by Jim Curlin and Ezra Clark experts from the UN Environment OzonAction and also several experts from the IIR commissions.*

# IIR-UN Environment Cold Chain Brief on Commercial, Professional and Domestic Refrigeration



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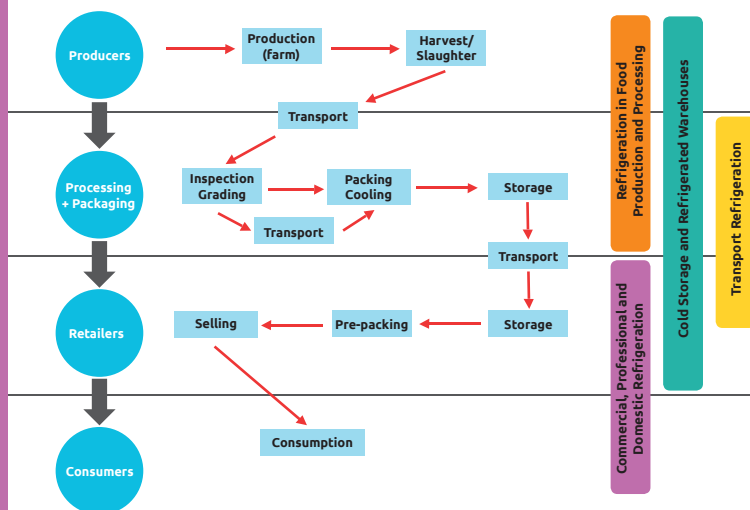
# 2 The Cold Chain

## Summary

Due to the complex nature of the cold chain and the high temperature dependency of post-harvest or post-mortem deterioration in food, temperature control in the food chain is vital. Temperature control tends to become less well controlled at the retail/professional and domestic stages of the cold chain. The food chain is responsible for greenhouse gas emissions through direct (refrigerant emissions) and indirect (energy consumption) effects. Published data for overall emissions for each section of a whole cold chain are relatively scarce. However, there is evidence to suggest that the retail sector has relatively high direct and indirect emissions compared to other sectors of the food cold chain. Domestic refrigeration has high overall indirect emissions (due to the large numbers of domestic refrigerators) but direct emissions are low due to low leakage of refrigerants and the use of low global warming potential (GWP) refrigerants. Refrigerant leakage is also low in the professional (catering) sector (for the same reasons) but there is evidence that indirect emissions are relatively high.

The “cold chain” refers to the various stages that a refrigerated product passes through, either until it is removed by a customer in a retail environment or unloaded from a delivery vehicle a few metres from its destination. From the moment a fruit or vegetable is harvested or an animal is slaughtered, the product starts to deteriorate. The deterioration of a product can be slowed by reducing the temperature at which it is stored. In fruits and vegetables, this slows down metabolic processes, which, in turn, slows spoilage. Reduced temperatures slow the growth of potentially harmful bacteria in animal products that are stored at frozen temperatures, allowing them to be shipped all over the world with minimal food safety risks. It is important that suitable temperature control be maintained from as soon as is feasible to as close as possible to consumption. From the raw materials stage to the various distribution storage facilities a commodity passes through, transport refrigeration keeps it at the temperature required to maximise storage life and quality for many days, weeks and months between cold storage facilities.

**The Cold Chain**



©Diagram : Judith Evans and IIR

Fig.1

The cold chain is often quite complex, with foods being chilled or frozen on more than one occasion. Worldwide about 400 million tonnes of food are preserved using refrigeration. The overall volume of cold stores (refrigerated warehouses) around the globe is about 600 million m<sup>3</sup>. The IIR estimates that the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion, including 1.5 billion of domestic refrigerators. 90 million of commercial refrigerated equipment (including condensing units, stand-alone equipment and centralized systems) are operating in the world. There are also 4 million refrigerated road vehicles (vans, trucks, semi-trailers or trailers), 1.2 million refrigerated containers (reefers) and 477,000 supermarkets, with a footprint ranging from 500 to 20,000 m<sup>2</sup> in operation and where 45% of the electricity consumed is used by refrigeration equipment (IIR, 2015<sup>2</sup>).

## 1 Introduction

The economic investment in food refrigeration technologies throughout the cold chain is tremendous in terms of refrigeration equipment worldwide. Refrigeration technologies are some of the most energy-intensive technologies used in the food supply chain and pose a number of sustainability-related challenges. Refrigeration accounts for about 35% of electricity consumption in the food industry (Guilpart, 2008<sup>1</sup>). Overall the cold chain is believed to be responsible for approximately 2.5% of global greenhouse gas emissions through direct (refrigerant emissions) and indirect (energy consumption) effects.

<sup>1</sup>Guilpart, J., 2008. *Froid et alimentation: Sécurité, sûreté ou procédé*, Conférence Centenaire du froid. Paris, France.

<sup>2</sup>IIR, 2015. 29<sup>th</sup> Note: *The Role of Refrigeration in the Global Economy*.



# 3 Overview of Commercial, Professional and Domestic Refrigeration

Fig.2: Typical professional refrigerators.  
Fig.3: Typical commercial refrigerators.  
Fig.4: Typical domestic refrigerators.

Commercial, professional and domestic refrigeration all occur at the later stages of the cold chain at the point where the retailer stores or the consumer purchases the food product. Commercial refrigeration encompasses supermarkets, convenience stores and bars and restaurants where food is on display for purchase by consumers. Smaller systems are integral units of usually less than 3 kW electrical consumptions but the sector also covers larger systems with multiple cabinets served by central refrigeration systems. Vending machines, water coolers, drinks fountain and small displays are considered as commercial refrigerators. Professional refrigeration encompasses restaurants, cafés and fast food outlets where food is stored before being prepared for the consumer. Professional cabinets are also sometimes found in supermarkets where they are used behind delicatessen displays for storage of food. Most of the appliances are solid door cabinets used for food storage (chilled or frozen) but blast coolers and freezers are also part of this sector. The vast majority of the cabinets sold are integral cabinets (plug in units with the refrigeration system on board) but remote units (where the refrigeration system is separate from the cabinet) are also available. Professional vaccine/blood/plasma units could be found in the pharmaceutical sector. Domestic refrigeration is used in consumers' homes to store food in chilled or frozen form. Domestic refrigerators are almost universally integral systems with an electrical consumption of around 20-150 W.



Fig.3



Fig.2



Fig.4

# 4

## Current Issues and Market Trends

### 4.1. Temperature performance

Temperature is the prime factor controlling food quality and bacterial growth on foods. Generally, lower temperatures will achieve longer storage life. For chilled products there are minimum storage temperatures which are dependent on either the initial freezing point or a point where chilling injury occurs.

#### 4.1.1. Temperature control in catering establishments

Limited information is available on temperature control in catering establishments. In Europe recent legislation has been applied to limit maximum temperatures and energy use in professional cabinets. Under the Ecodesign (Directive 2009/125/EC) and Energy Labelling (Directive 2010/30/EU) Directives most common types of chilled professional cabinets cannot be sold in Europe unless they achieve an internal temperature of between -1 and 5°C when tested in a laboratory at an ambient temperature of 30°C. Likewise frozen professional cabinets cannot be sold in Europe if they are unable to maintain temperature below a maximum of -15°C.

#### 4.1.2. Temperature control in retail supermarkets

Temperatures in cabinets are specified by food safety regulations, standards, and by supermarkets' own specifications. However, differences between the recommended temperature and the real working temperatures can sometimes be observed. This can be due to variations in position of the control temperature probe(s), set up of the cabinet, or variations in the use of the cabinet.

Apart from the home, retail display is the weakest link in the food cold chain. Derens *et al.* (2007<sup>3</sup>) found that once food entered the supermarket the number of samples below 4°C (for meat) or 6°C (for yogurt) was less than 70%. This was further reduced to 16% during transport to the home and only recovered to 34% in the home. Mean food temperatures in chilled multi-deck cabinets in stores can vary greatly, with a study in the UK finding mean temperatures ranging from -1°C to 16°C (James and Evans, 1990<sup>4</sup>). This range causes food manufacturers problems when defining shelf life and results in shelf lives that are either unduly cautious or potentially risky. Individual cabinets are also often subject to large ranges in temperature and variations between locations within the cabinet (Evans *et al.*, 2007<sup>5</sup>, Evans and Swain, 2010<sup>6</sup>). The ranges in temperature are partially encouraged by the test standards used to accredit cabinet performance where temperature ranges of 6, 8 or even 11°C are allowed.

#### 4.1.3. Temperature control in domestic refrigerators

Temperature control of food in the home is vitally important. Evidence suggests that over 70% of food poisoning cases originate in the home and if food is stored in less than optimal conditions the potential for growth of pathogenic organisms exists. In the past decade there have been at least 15 surveys of temperatures in domestic refrigerators. The results are very similar, with overall mean temperatures ranging from 4.5 to 6.6°C and maximum temperatures from 11 to 14°C. These results imply that the average temperature of at least 50% of domestic refrigerators is above 4.5°C.

In what is the most recent and comprehensive survey of temperature control in domestic refrigerators (carried out in the UK) it was found

that the overall mean internal temperature of all refrigerators (671 appliances) was 5.3°C (Gemmell *et al.* 2017<sup>7</sup>). The maximum overall mean temperature in a single refrigerator was 14.3°C and the overall minimum mean temperature was -4.1°C. The overall mean temperature of freezers in the survey (745 appliances) was -20.3°C.

### 4.2. Energy consumption

#### 4.2.1. Energy consumption in catering establishments

Professional cabinets used in catering establishment are reported to consume 12% of the refrigeration energy used in the sector. The average energy consumption claimed for chilled cabinets is 2,920 kWh per year and for frozen is 5,475 kWh per year (MTP, 2006<sup>8</sup>). There are few published data on energy consumption of professional cabinets in actual use. Unpublished data collected from real life usage of cabinets indicates that there are large differences in energy consumed by different cabinets. There are also large differences in the energy consumed by the same cabinet model in different locations, likely due to variations in usage and impact of local conditions such as ambient temperature, drafts from doors or proximity of warm appliances.

#### 4.2.2. Energy consumption in retail supermarkets

Refrigeration is often the largest energy load in a supermarket. The energy consumption of supermarkets depends on business practices, store format, product mix, shopping activity and the equipment used for in-store food preparation, preservation and display. The annual electrical energy consumption can vary widely from around 700 kWh/m<sup>2</sup> sales area in hypermarkets to over 2000 kWh/m<sup>2</sup> sales area in convenience stores (Tassou *et al.*, 2011<sup>9</sup>). The refrigeration systems account for between 30% and 60% of the electricity used, whereas lighting accounts for between 15% and 25% and the HVAC equipment and other utilities such as bakery use the remainder. Gas is normally used for space heating, domestic hot water and in some cases for cooking and baking and will vary from zero in small stores such as petrol filling stations where gas is not used, to over 250 kWh/m<sup>2</sup> in hypermarkets. In some stores the gas energy consumption can be as high as 800 kWh/m<sup>2</sup>. Tassou *et al.* (2011<sup>9</sup>) report energy use for varied supermarket sizes. In convenience stores the average electrical energy consumption of the stores using integral refrigeration equipment was approximately 300 kWh/m<sup>2</sup> higher than the stores using predominantly centrally located remote refrigeration equipment. Work carried out by Evans and Swain (2010<sup>6</sup>) showed that based on cabinets then on the market there were large overall differences in energy consumption between cabinet types and also between cabinets of each type when tested to EN23953 or EN441. Large energy savings could easily be achieved by selecting the best model within each cabinet type and by examining methods to reduce the range in temperature in cabinets. Many options are available to reduce energy consumption in supermarkets. In a study carried out by Evans *et al.* (2016<sup>10</sup>) 81 different technologies and their potential to save direct and indirect emissions in supermarkets were examined. Most of the carbon saving measures could be applied to currently installed cabinets and include cabinet doors, strip curtains, air deflectors/guides (all on open fronted cabinets) and improved fans. Additional options are available for new cabinets and these include optimisation of air flow in the cabinet, using high efficiency evaporators and micro-channel heat exchangers.

<sup>3</sup>Derens, E., Palagol, B., Cornu, M., Guilpart J., 2007. *The food cold chain in France and its impact of food safety*. IIR IRC2007, Beijing, China.

<sup>4</sup>James, S.J., and Evans, J.A., 1990. *Temperatures in the retail and domestic chilled chain. Processing and Quality of Foods*. Vol. 3. Chilled Foods: The Revolution in Freshness. Elsevier Applied Science Publishers, London, 3.273-3.278.

<sup>5</sup>Evans, J.A., Scarcelli, S., and Swain, M.V.L., 2007. *Temperature and energy performance of refrigerated retail display cabinets under test conditions*. Int. J Refrigeration. Vol. 30 pp 398-408.

<sup>6</sup>Evans, J.A., and Swain, M.V.L., 2010. *Performance of retail and commercial refrigeration systems*. IIR ICC2010, Cambridge, UK.

<sup>7</sup>Gemmell, A., Foster, H., Siyanbola, B., and Evans, J., 2017. *Study of Over-Consuming Household Cold Appliances*. Report Number: HPR187-1003.

<sup>8</sup>MTP, 2006. *Sustainable products 2006: Policy analysis and projections*.

<sup>9</sup>Tassou, S.A., Ge, Y., Hadawey, A. and Marriott, D., 2011. *Energy consumption and conservation in food retailing*, Applied Thermal Engineering, Volume 31, Issue 2, 2011, Pages 147-156.

<sup>10</sup>Evans, J., Maidment, G., Brown, T., Hammond, E., Foster, A., 2016. *Carbon reduction opportunities for supermarkets*. IIR ICC2016, Auckland, New Zealand.

### 4.2.3. Energy consumption in domestic refrigerators

In Europe manufacturers have been reducing the energy consumed by domestic refrigerators and freezers since the instigation of energy labelling in 1995. There is substantial information on energy used by domestic refrigerators in Europe under test conditions as assessment of energy use is part of energy labelling. The test conditions do not include simulated usage as the tests are carried out with closed doors in a test environment. They therefore do not fully mimic real life energy usage. A recent study of refrigerators in the UK collected energy consumption data from 665 cold appliances (Gemmell *et al.*, 2017<sup>3</sup>). The overall mean annual consumption measured was 354 kWh/year, based on the entire monitored period of approximately 7 days. Although the energy efficiency of domestic refrigerators has improved considerably there are still options to reduce energy consumption through use of advanced insulation, compressor efficiency improvements, and optimisation of the refrigeration system operation/control and heat exchangers.

## 4.3. Refrigerant (direct) emissions

### 4.3.1. Refrigerant emissions in catering establishments

Data on direct emissions from catering cabinets are scarce. They are however, very likely to be similar to those from domestic refrigeration as the technologies used to produce the cabinets are similar. Emissions of HFCs from German commercial refrigeration between 1996 and 2002 were calculated by Schwarz (2005<sup>11</sup>). The emissions from catering cabinets estimated in the report were 1.5% which is similar to the IPCC (Intergovernmental Panel on Climate Change) estimates of 0.5-3% (IPCC, 2005<sup>12</sup>).

### 4.3.2. Refrigerant emissions in retail supermarkets

In larger remotely operated cabinets (operated from a central refrigeration plant) the direct emissions from the refrigeration system have a large impact. Emissions are largely attributed to HCFC and HFC refrigerant leakage. Leakage of refrigerant from supermarkets varies considerably. In industrialised countries integral cabinets have been shown to have minimal leakage (<1% per year) whereas leakage from remote refrigeration plant can vary from an average of 3% per year at best, to up to an average of 20-30% per year at worst. There is evidence that leakage rates can be reduced to low levels. This has been achieved through a change in management, system or technology and to better training, skills and qualifications of operators and maintenance teams. A number of options are available to reduce direct emissions from supermarkets. Evans *et al.* (2016<sup>10</sup>) showed that significant carbon savings could be achieved by reducing refrigerant charge, applying good refrigeration engineering practices, applying lower GWP refrigerants or by applying secondary fluids with centralised refrigeration systems. In order to achieve continuing reductions in refrigerant leakage it is necessary to gain a better understanding of where and why systems leak. Good maintenance records can help to identify high risk areas and components within systems and allow operators to prioritize their refrigerant containment activities.

### 4.3.3. Refrigerant emissions in domestic refrigerators

Evidence from sources such as Heap (2001<sup>13</sup>) and RAC (2005<sup>14</sup>) indicate that refrigerant losses from domestic refrigerators in industrialised are extremely low (less than 1% per year). Schwarz (2005<sup>11</sup>) estimated emissions of HFCs from German domestic refrigerators between 1996 and 2002 to be 0.3%, which is similar to the IPCC estimates of 0.1-0.5%. This assumes that refrigerant is removed and destroyed at end of life of the appliance. In developing countries where road conditions are often poor (this may cause pipes to fracture or pipe connections to become loose) and servicing and at the end-of-life are poorly controlled due to lack of regulation the leakage rates may be considerably higher. Giz (2017<sup>15</sup>) estimate that leakage rate over the life of an appliance may be 27% in developing countries.

<sup>11</sup>Schwarz, W, 2005. *Emissions, Activity Data, and Emission Factors of Fluorinated Greenhouse Gases (F-Gases) in Germany 1995-2002. Research Report 201 41 261/01 UBA-FB 000811/e.*

<sup>12</sup>IPCC/TEAP, 2005. *Special Report: Safeguarding the Ozone Layer and the Global Climate System. Chapter 4. Refrigeration.*

<sup>13</sup>Heap, R.D., 2001. *Refrigeration and air conditioning – the response to climate change. Bulletin of the IIR No 2001-5.*

<sup>14</sup>RAC (Refrigeration and Air Conditioning Magazine) Conference June 2005.

<sup>15</sup>Giz, 2017. <http://www.green-cooling-initiative.org/technology/domestic-refrigeration/green-cooling-potential>.

# 5 Current Refrigerants Used and Potential Alternatives

## 5.1. Refrigerants used in catering

Traditionally HFC refrigerants were used in catering cabinets. More recently a number of manufacturers have moved to R290 (propane), partly due to its low GWP but also because it is an efficient alternative.

## 5.2. Refrigerants used in supermarkets

Existing supermarket refrigeration systems are predominately based upon HCFC and HFC refrigerants, although use of R744 (CO<sub>2</sub>) and hydrocarbons is increasing. Alternative systems such as secondary systems where a fluid such as glycol is cooled by a primary refrigeration system and then pumped to the cabinets are often used in Scandinavian countries. Other systems include the use of water to cool the condensers of integral cabinets and creating cold air in a central location that is then used to directly cool the cabinets (chilled cabinets only).

## 5.3. Refrigerants used in domestic refrigerators

Between 35% - 40% of domestic refrigerators operate on R600a, a hydrocarbon with a GWP of 3 (European Parliament Regulation No 517/2014, 2014<sup>16</sup>). Although flammable, R600a is an efficient refrigerant (MacLaine-Cross and Leonardi, 1996<sup>17</sup>). Generally refrigerators operating on a hydrocarbon will be helium leak tested prior to being charged with refrigerant at the factory. This has been shown to provide a high level of leak detection and there have been few instances of leaks of refrigerants in consumers' homes. All major European, Japanese and Chinese manufacturers produce refrigerators operating on R600a and the technology dominates the market in Europe, Japan and China. The 2010 Technology and Economic Assessment Panel (TEAP) Progress Report (UNEP, 2010<sup>18</sup>) reported that "It is predicted that at least 75 percent of global new refrigerator production will use hydrocarbon refrigerants in 10 years."

**Table 1: Summary of current and alternative refrigerants**

Commercial, Professional and Domestic Refrigeration		
Types of refrigeration	Current higher GWP refrigerants (GWP kg.CO <sub>2</sub> )	Alternative lower GWP refrigerants (GWP kg.CO <sub>2</sub> )
Commercial	Remote and integral: HFC-134a (1300); HFC-404A (3920), HCFC-22 (1810)	Remote: R-744 (1) Integral and secondary: HC-290 (5), HC-1270 (1.8) Remote and integral: wide range of HFO and HFO blend refrigerants
Professional	HFC-404A (3920), HFC-134a (1300)	HC-290 (5), HC-600a (20), wide range of HFO and HFO blend refrigerants
Domestic	HFC-134a (1300)	HC-600a (20)



# 6 Development Perspectives and Challenges

## 6.1. Professional refrigeration

The fundamental design of professional refrigerated cabinets has changed little over the past 20 years. Major step changes that have improved efficiency have not occurred. Manufacturers have difficulty justifying the higher costs of energy saving components because users' emphasis is on the first cost of units rather than life cycle costing. Considerable energy savings are achievable using available technologies but one of the major issues is persuading end users to purchase the most efficient cabinets.

## 6.2. Commercial refrigeration

Considerable reductions in carbon emissions are possible from supermarket cabinets (Evans *et al.*, 2016). Much of the savings could be achieved by applying doors, strip curtains or technologies that reduce air infiltration to open fronted cabinets. Further reductions could be achieved by use of evaporator optimisation and new evaporator technologies. The use of alternative refrigerants with low GWP has considerable potential to reduce direct emissions. The main challenge is to apply these technologies economically and to achieve paybacks that are acceptable to the cost sensitive supermarket sector.

## 6.3. Domestic refrigeration

There is still evidence that temperatures in home refrigerators are higher than optimal. Over the past 30 years there have been a large number of surveys on temperatures in domestic refrigerators and all have concluded that few domestic refrigerators operate optimally in real life use by consumers. The energy used by domestic refrigerators has reduced considerably since energy labelling of appliances was introduced in the 1990's, but there is potential to improve food safety and quality through operation at more optimal temperatures (generally considered to be 0-5°C in the refrigerator and <-18°C in the freezer) which in turn may reduce food wastage and provide overall reductions in carbon emissions.

# 7 Technical Challenges and Potential

## 7.1. Professional refrigeration

Initial improvements in performance are relatively simply and involve use of the best components and technologies. In 2004, Pedersen<sup>19</sup> published a study showing improvements to cabinets which reduced energy use to 74% (chillers) and 47% (freezers) of original usage (from 6.26 kWh/day to 1.62 kWh/day for the chillers and from 8.53 kWh/day to 4.54 kWh/day for the freezers). The energy savings were achieved by changing the refrigerant, using energy efficient components and optimising heaters, door seals and the control system. The greatest savings were achieved by optimising the door seals, using DC fans and by using compressor discharge gas for evaporator water evaporation.

In the future further improvements will be required to achieve the 'best' energy labels. Technologies and systems such as inverter driven compressors, alternative defrosting methods and strategies, advanced control systems, removal of gasket and anti-condensate heaters, liquid line solenoids and advanced insulation will all play a part in future energy reduction strategies.

## 7.2. Commercial refrigeration

Technical challenges in commercial refrigeration involve the move to low-GWP refrigerants, and improving temperature control whilst also reducing energy consumption. Many of the issues are not just technical but also behavioural. For example there is a perception that a barrier between the shopper and the food may reduce sales and this has made supermarkets reluctant to apply doors to open fronted cabinets.

## 7.3. Domestic refrigeration

As with professional and commercial cabinets there are technical challenges to reduce energy consumption and ensure good temperature control. Although domestic refrigerators have undergone considerable energy reductions over the past 30 years there is still potential for further reductions. The primary challenge is applying new technologies economically.

## 7.4. Related over-arching issues

A number of common issues are relevant to commercial, professional and domestic refrigeration. Many very low GWP refrigerants are flammable or operate at high pressures. The uses of these refrigerants require designers and technicians to understand the safety issues and to ensure systems are designed and operated to ensure the safety of end users. This often involves training and knowledge of safety standards and their application.

## 7.5. Related driving policies

The EU Ecodesign Directive (Directive 2009/125/EC) is a framework directive that obliges manufacturers of energy consuming products to reduce the energy consumption and sometimes also other negative environmental impacts occurring throughout the product life cycle. The Directive is complemented by the Energy Labelling Directive (Directive 2010/30/EU). Both domestic re-

<sup>16</sup>European Parliament. Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, 2014.

<sup>17</sup>MacLaine-Cross, I.L. and Leonardi, E., 1996. Comparative performance of hydrocarbon refrigerants. IIR Commissions E2 E1 B1 B2 Melbourne, Australia.

<sup>18</sup>UNEP, 2010. 2010 Progress Report: Assessment of HCFCs and Environmentally Sound Alternatives, UNEP Technology and Economic Assessment Panel, p.37.

<sup>19</sup>Pedersen, R., 2004. Advantages and disadvantages of various methods for chilling of poultry, Landbrugsministeriets Slagteri-og Konserverlaboratorium, Copenhagen, Denmark, Report No. 189.

frigerated appliances and professional refrigerated cabinets are included under the directives. In the case of domestic appliances similar legislation is applied in almost all developed countries (Figure 5).

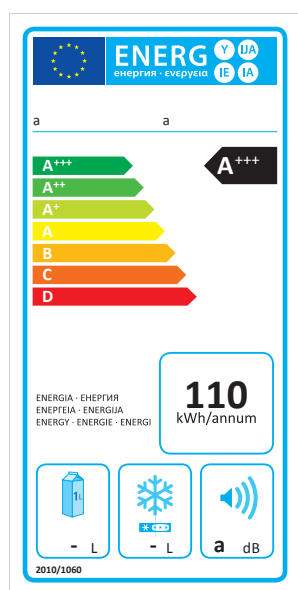
Refrigeration and Air Conditioning Industry witnessed considerable development and modernization in the last 3 decades partly as result to the international environmental policies where many refrigerants that have been used efficiently for decades, are held responsible to the Ozone Layer Depletion as well as Global Warming. The phase-out of ozone depleting substances (ODSs), under the Montreal Protocol, triggered significant changes in the industry moving towards alternative refrigerants and technologies that has zero-ODP (Ozone Depletion Potential).

In October 2016, the Kigali Amendment to the Montreal Protocol brought another dimension to the mandate of the Montreal Protocol by adding the control of production and consumption of hydrofluorocarbons (HFCs) under its mandate which will have major contribution towards the fight against climate change.

social and technical areas i.e. food industry, health, refrigeration, transportation, tourism, etc. The norms and directions for cold chain technology selection that has less environmental impact, energy efficient operation and affordable economics is scattered amongst different groups and entities within the same country. In September 2015, International Community adopted the 2030 Sustainable Development Goals (SDGs) stipulating Goal #2 «Zero Hunger» as the second global goal which needs to be achieved by 2030. This automatically means the urgent need to efficiently manage the portfolios of «Food Security» & «Food Waste» which depends on the cold chain capabilities. While this goal can be noted as the main goal with direct relation to cold chain, other goals are also connected to the cold chain business i.e. Goal #3: Health and Wellbeing, Goal # 9: Industry Innovation and Infrastructure, Goal # 12 Responsible Consumption and Production as well as Goal #13: Climate Action. Therefore, the integrated approach in addressing the cold chain challenges can lead to multi socio-economic and environment benefits.

<sup>20</sup> UNEP, 2014. International Standards in Refrigeration and Air-Conditioning. An introduction to their role in the context of the HCFC phase-out in developing countries.

Fig.5: European professional cabinet energy label (left), typical domestic energy labels from across the World (right)



©www.ec.europa.eu/energy/eepr/labels

©Diagram : Judith Evans

Control of HFCs production and consumption will add to the climate benefits already achieved by the Montreal Protocol through the phase-out of ODSs including CFCs and HCFCs. The emissions of HFCs are also listed within the group of GHGs (Greenhouse Gases) under the Climate related conventions i.e. Paris Agreement and previously the Kyoto Protocol. However, actions to specifically control HFCs emissions within the climate regime are not yet set except for reporting requirements under the UNFCCC (UN Framework Convention on Climate Change).

The refrigerant climate impact of refrigeration equipment depends on direct and indirect effects. The direct effect is from its GWP (Global Warming Potential) and amount of a refrigerant emitted to the atmosphere (either from a leak, accident, or from improper handling or disposal). The indirect effect is associated with the energy consumed during the operation of equipment which, over its lifetime, occurs as a result of the CO<sub>2</sub> (CH<sub>4</sub> to lesser extend) produced by fossil fuel power plants, and is commonly greater than the direct effect. Minimizing direct and indirect impacts, of all types of refrigerants, emissions should be addressed through improved design, better field commissioning and maintenance practices, sound decommissioning procedures and enforcement to local relevant standards and regulations.

There are several principal organisations developing standards related to the refrigeration and air-conditioning sector. The UNEP International Standards in Refrigeration and Air-Conditioning booklet (UNEP, 2014<sup>20</sup>) summarises the main international standardisation organisations and provides some examples of national and regional standards organisations.

The cold chain sector is one of the most important but overlooked business segments in terms of being addressed in a holistic approach. This is because it crosscuts with different economic,

## Conclusions

Commercial, professional and domestic refrigerators are the last stages in the cold chain where food is stored before consumption. The sectors are characterised by several challenges such as temperature maintenance and energy reduction. Commercial refrigeration also has higher emissions from refrigerants related primarily to the use of larger remotely operated refrigeration systems. All sectors have the potential for significant energy reduction.

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# COLD CHAIN TECHNOLOGY BRIEF

## FISHING VESSEL APPLICATION



*Acknowledgement: This Cold Chain Brief was prepared by Paul de Larminat (IIR Expert), has been reviewed by Artie Dubrie and Alvin Jose, experts from the UN Environment OzonAction and also several experts from the IIR commissions.*

# IIR-UN Environment Cold Chain Brief on Fishing Vessel Applications



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## Summary

Fishing vessels are primarily intended to catch fish, but must also provide an adequate cold chain until the fish is unloaded. When not consumed fresh, fish is processed in different ways, like in prepared dishes, freezing and canning. This processing can be done in land-based factories or on board large factory ships. These steps involve refrigeration, with implementations depending on the modes of fishing and processing. The applications of refrigeration for the various process needs in fishing vessels are presented, with technologies currently in use. HCFC-22 (R-22) is still the widely dominant refrigerant, but it is among the ODS substances that parties to the Montreal protocol are required to phase-out. Under the Kigali agreement, all countries will also have to gradually phase down the use of hydrofluorocarbons (HFC's) (UNEP, 2017<sup>1</sup>). Supporting the Montreal Protocol, controlled substances used in mobile marine systems will have to be addressed.

Alternatives that are not ozone layer depleting and having zero or low global warming potential are commercially available for new refrigeration systems. But for the existing R-22 fleets, the challenges are on the servicing of existing R-22 systems requiring continued cost-effective availability of R-22 refrigerants and equipment supplies. For small capacity direct expansion (D-X) systems, it is generally possible to retrofit to non-ODS substances. But for large flooded systems, retrofitting to R-22 alternatives is not a recommended option.

<sup>1</sup>UNEP, 2017 : <http://ozone.unep.org/en/unga-high-level-event-ratification-kigali-amendment>

## 1 Introduction

This brief will present the process needs and applications of refrigeration on board refrigerated fishing vessels. Currently used technologies and refrigerants will be presented, along with the possible alternatives for new systems. The issues related to the management of existing fleets and implications to the Montreal Protocol on ozone depleting substances will also be presented.



# 2 Overview of Refrigerated Fishing Vessels

## 2.1. Types of fishing vessels

Fishing and the related industry are highly diversified, depending on the mode of catching fish and the circuit between catch and consumption. When not consumed locally, fish can be processed in different ways: frozen as fresh catch, or fillets, prepared dishes, and canning. This can be done in land-based factories, or at sea on board “factory ships”.

The total number of fishing vessels in the world is estimated at about 4.4 million, from which over 80% are less than 12 m long. Overall, Asia and the Pacific have the largest fleet, accounting for 73% of the world total. About 2% of all motorized fishing vessels are industrialized fishing vessels of 24 m or more (UNEP, 2016<sup>2</sup>). Fishing vessels are also different by the kind of fishing gear they are using. For large scale fishing, the most widely used methods are purse seine and long lines, illustrated in Figures 5 and 6.

Small artisanal fishing vessels as the type seen in Figure 3 do not have installed refrigerated systems. Motorized small-scale fishing vessels load up ice every morning from the harbour as the duration of fishing is for few hours and the catch is preserved during that period with the ice as shown on Figure 2. Medium to Large commercial scale vessels going out for mid distance (of the order of two weeks sailing) typically have Refrigerated Sea Water (RSW) tanks and ice making machines on board. Large industrial-scale vessels going out for long distance and/or time (typically several months sailing) need deep freezing for fish conservation. Depending on species of fish caught, fishing gear and process needs, these vessels often have complete factory installations with various combinations of blast freezers, plate freezers, RSW tanks and ice machines.

## 2.2. Refrigeration Technologies

### 2.2.1. Brine cooling and RSW

Some species of fish are mostly preferred for canning like tuna, sardines or anchovies. Canning is often done in land-based sea-food processing factories. A common practice is to quickly freeze the whole fish on board by immersion in a brine tank at around -20°C, as soon as it has been caught. Afterwards, it can be stored in the tank or in cold rooms. Brine tanks are also widely used for purse seine fishing, because the method is ideal to quickly freeze large batches of simultaneous catch inherent to this fishing mode (Awira, 2015<sup>3</sup>).

In warm climates, a quick pre-cooling of catches is needed before putting the fish in ice; this is carried out by immersing the fish in sea water chilled by RSW chillers. Sea water is generally cooled close to or slightly above its freezing point (-2°C). In small boats without chillers on board, water can be chilled by melting stored ice in a seawater tank.



Fig.1



Fig.2



Fig.3



Fig.4

<sup>2</sup> UNEP, 2016. TEAP TF-XXVII-4 Report; annex 2 / June 2016

<sup>3</sup> Ribanataake Awira, 2015: "Refrigerant Consumption in Fishing Vessels operating in the Waters of Pacific Islands Countries". MOP27 Side event. Nov.1, 2015, Dubai-UAE

### 2.2.2. Plate and Blast freezers

Thin consumer sized fillets are generally frozen in plate freezers, while larger cuts including large whole fish are frozen in brine tanks or blast freezers. In a plate freezer, trays containing the fillets are typically placed on stacks of plates as shown in Figure 7. These plates are refrigerated by evaporation of refrigerant inside these plates. The heat transfer is essentially achieved by close contact between the refrigerated plates and the goods in the trays. The process is different than blast freezers: in these, cold air is blown onto the goods to be frozen, like in Figure 8. This air is cooled by air cooling coils. In both cases, the operating temperature is around  $-40^{\circ}\text{C}$ , either for the plates or for the refrigerated air; but it can be even lower, down to  $-70^{\circ}$  when "ULT" (Ultra Low Temperatures) is desired, like for sushi or sashimi.

### 2.2.3. Air cooling

Air cooling is needed at various stages of processing. Working areas need clean rooms with temperature control and hygienic measures. For storage, the air in the hold at positive temperature is also often cooled, especially in warm countries. Frozen goods in factory ships are stored in cold rooms at around  $-25^{\circ}\text{C}$ .

Air conditioning for crew comfort and provision stores for the daily life of crews are not addressed in this document, which focuses on "process" applications.

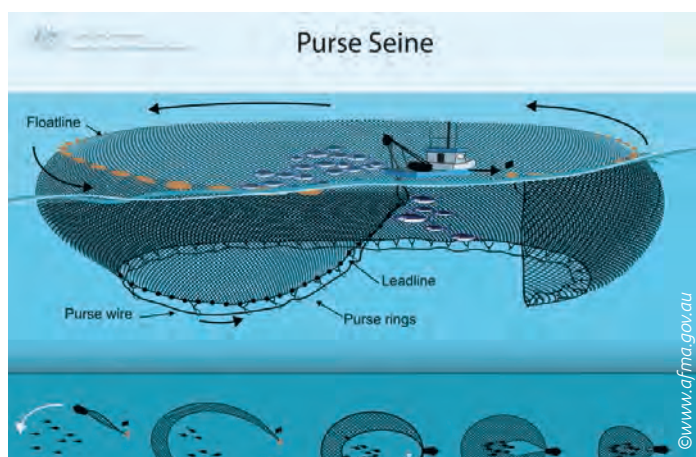


Fig.5



Fig.7

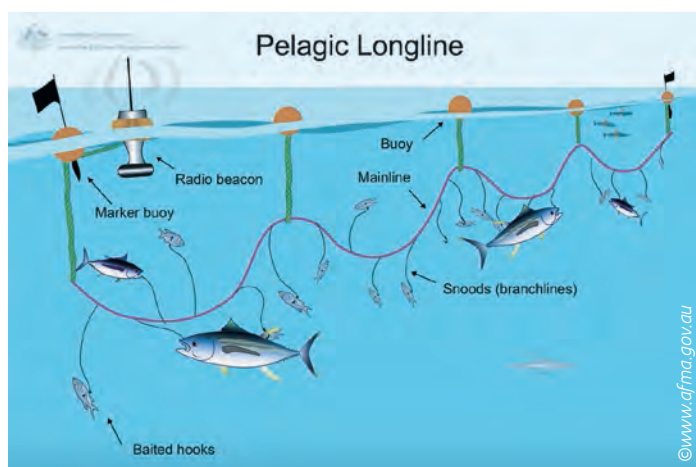


Fig.6



Fig.8

- Fig.1: Frozen fillets
- Fig.2: Fresh fish stored in ice
- Fig.3: Small fishing boats - Thailand
- Fig.4 : Tuna seiner fishing vessel – 90 m long
- Fig.5: Pelagic Long Line
- Fig.6: Purse seine fishing
- Fig.7: Loading a plate freezer
- Fig.8: A blast freezer

# 3 Current Issues and Market Trends

Fig.9: Centralised flooded system using a single-component fluid: R-22 or ammonia.

Fig. 10: Example of cascade with CO<sub>2</sub> for low temperature and brine for medium temperature.

## 3.1. Process needs - Similarities and differences with other food industries

Most of the process needs are similar to land-based food processing applications, like cutting and processing in clean rooms, freezing in plate or blast freezers, storage etc. As the process needs are similar, technologies are derived from those used for land-based applications, with specific customisation to the marine environment ("marinization").

Given the significant constraints specific to the marine environment, very high reliability is expected. Equipment must be suitable for the ship's motion, and withstand corrosion in the marine environment. There are also material compatibility constraints for seawater cooled condensers. The common practice is to use shell and tube condensers. Copper-nickel tubes are compatible with sea water, and with synthetic fluids such as R-22, but copper alloys are not compatible with ammonia. Titanium is in practice the sole material that is compatible with ammonia and seawater simultaneously.

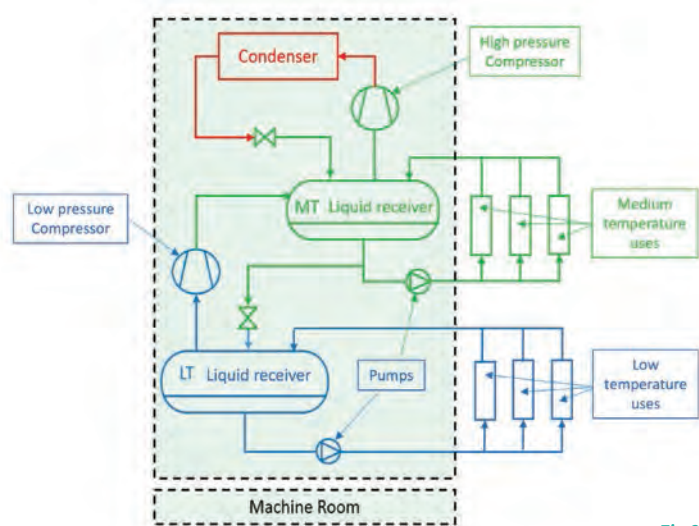
## 3.2. Systems architecture

There are many possible systems architectures for process applications. The different needs may be fulfilled by independent systems, or the systems may be centralised, meaning that a combined system is serving all refrigeration demands (RSW, cooling, freezing) from a central machine room (Norden, 2000<sup>4</sup>). In general, larger vessels tend to have a higher degree of integration. They typically have a centralised system providing refrigeration at two different levels of evaporation temperature, around -38°C for freezing (Low Temperature, "LT"), and about -8°C for other needs like air cooling in working areas and holds, seawater cooling etc., ("Medium Temperature, "MT"). Large systems are generally pump-flooded systems, as per Figure 9. They currently use single-component refrigerant, usually R-22, but the use of ammonia is increasing. In such systems, the refrigerant charge is large (several tonnes), with long piping and many connections, often causing relatively high refrigerant leakage. Smaller systems are often D-X systems. They are mostly used in air-cooling applications (in holds and cold rooms), but they are inadequate for plate freezers. They are less energy efficient than flooded systems, but the initial cost is lower, and they require a lower refrigerant charge (of the order of a few hundred kilograms).

## 3.3. Climate considerations

Given the nature of the industry, fishing vessels can be found to be working in extreme and varying climates. But refrigeration systems are inside the vessel and condensers are generally cooled with seawater. Even in warmer climates, seawater temperature practically never exceeds 32°C, which is still rather simple to design for. Therefore, although a hot climate must be taken into account in the design when applicable, it is not a major technical issue.

<sup>4</sup>Norden, 2000. "Alternatives to HCFC as refrigerant in Fishing Vessels", ISBN 92-893-0504-5.



©Diagram: Paul de Larminat

Fig.9

## 3.4. Safety Management on board

Refrigeration machinery must be built according to an approved existing equipment safety standard such as that of the EN-378 or equivalent. For on board refrigerated systems, there are currently no international agreed vessel-building codes. In keeping with industry practices, design decisions should be based on robust risk analyses conducted in coordination with classification societies, insurance companies and other key industry and public sectors stakeholders. This standard safety management approach is required for all types of refrigerant and technologies. It is to be noted also that some countries have required national legislatively enforceable maritime standards that can be applicable also to fishing vessels.

In a design per Figure 9, most of the refrigerant charge is in the machine room, installed with leak detectors and adequate ventilation and very restricted access, especially if the refrigerant is flammable. Yet, although to a lesser amount, there is also some refrigerant in the working or storing ("use") areas. Although non-flammable fluids are preferred, experience with ammonia has shown that such designs can be implemented with acceptable safety, providing the system is designed accordingly, with proper training of crew, and adequate operational procedures and maintenance.

Having only non-flammable fluids, especially in working areas, is always preferred for safety. In addition to its high efficiency, it is a reason why CO<sub>2</sub> is now widely acknowledged as suitable in marine, especially for the low temperature stage of cascade systems. When combined with ammonia for the high stage, using CO<sub>2</sub> facilitates the elimination of ammonia from working areas, with confinement in the machine room. Figure 10 is an example of design for a centralised system without ammonia in working areas. It combines ammonia / CO<sub>2</sub> cascade for low temperature, and indirect system for medium temperature uses. Noting however that many other system architectures are feasible.



# 4 Current Refrigerants Used and Potential Longer-Term Alternatives

## 4.1. Existing refrigerated systems

It is estimated that 70% of the global fishing fleet is still using R-22 for all refrigeration applications (UNEP, 2016<sup>2</sup>, §-ES4). Prior to Montreal Protocol compliance requirements, R22 was a preferred option for reasons of efficiency, cost, and safety. Some ships built over the past two decades are using HFCs such as R-404A or R-507. In some recently built or refurbished ships, ammonia or ammonia/CO<sub>2</sub> cascades have been used

## 4.2. Blends versus single-component refrigerants

The technical acceptability of alternative refrigerants depends on the system architecture. Designers have the choice of using single-component fluids or blends, but all the blends proposed as alternatives to R-22 have some temperature "glide". Typical examples are the blends R-407A, R-407F, R-438A, R-448A and R-449A, 449B. All of these blends have a GWP in the range of 1300 to 2400, i.e. about half that of R-404A or R-507, but with a glide of approximately 6 to 7 K. This is generally acceptable in D-X systems, but is not desired in large flooded systems, where the glide can induce large performance penalties.

## 4.3. Lower-GWP Fluids– New systems

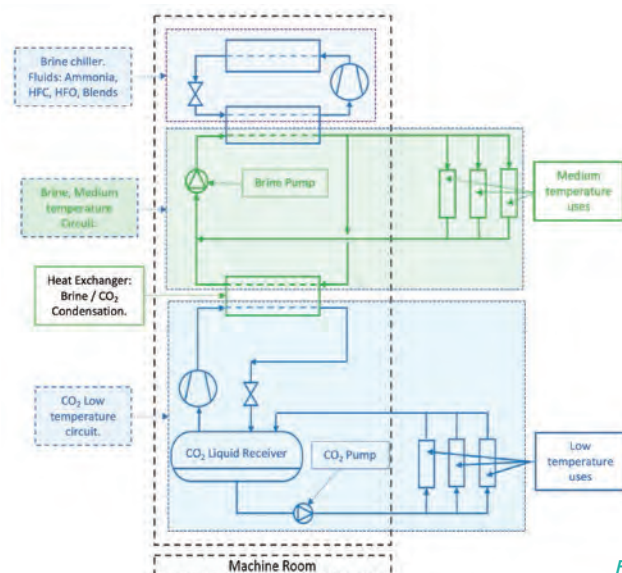
**D-X systems:** as aforementioned, the refrigerants proposed as alternatives to R-22 are blends with GWP of approximately 1300 to 2400 for non-flammable blends. Because of their glide, they are more complicated to handle than pure fluids. Systems must therefore be carefully designed, but one can generally consider that such blends are viable as alternatives to HCFC however with concerns on the GWP characteristics

**Brine and sea water RSW chillers:** Most marine chillers are derived from standard land-based chillers, with proper marinization. The choice of the refrigerants is not as critical for chillers as it is for large flooded systems because the refrigerant charge is limited, and the leak rates are much lower. For average temperatures of -10°C, medium to low GWP fluorinated refrigerants (such as R-134A) or lower GWP HFOs or blends like R-513A are used. For temperatures lower than -10°C, the refrigerants used mostly are R-404A or R-507. Suitable substitutes to R-404A or R-507 could be R-410A that has comparatively lower GWP, R-32 could also be suitable medium to low GWP substitute but has flammability concerns to be addressed. Ammonia is also suitable at all temperature levels, provided that the risk management is deemed acceptable considering the toxicity and flammability concerns of Ammonia.

**Centralised flooded systems:** To provide the cooling needs at medium and low temperature simultaneously with a common low-GWP refrigerant, ammonia is technically a straightforward alternative to R-22; it is cost effective and highly energy efficient, but with safety constraints. A possible alternative is to use two different refrigerants in a cascade, with CO<sub>2</sub> for the low-temperature level. Such CO<sub>2</sub> systems are compact and very efficient. The excellent heat transfer of CO<sub>2</sub> at low temperature improves the performance of freezers, reducing their capital cost and improving their productivity. If CO<sub>2</sub> is used for the LT stage, the remaining question is which fluid

to use for the medium stage. Various options are possible. Trans-critical CO<sub>2</sub> is feasible in theory, but it is not ready for fishing vessels. Other solutions require a different refrigerant for the medium-temperature stage of the cascade. The most widely used so far is ammonia. In ammonia/CO<sub>2</sub> cascade, safety is easier to manage than with 100% ammonia systems, because the ammonia charge is lower and can be contained in machine rooms. R-134a or one of its lower- GWP alternatives can also be used for the medium stage. Another option is to use "indirect" systems. In this case, a chiller cools brine to the desired "medium" temperature around -8°C. This brine chiller is used to serve the needs at this temperature level, and also to condense the CO<sub>2</sub> of the low temperature circuit, as illustrated in Figure 10. Like for RSW, this brine chiller can use a variety of refrigerants like ammonia, HFCs, HFOs, or suitable blends.

A draw-back of CO<sub>2</sub> is that it cannot reach the ultra-low temperatures (below -50°C) that are sometimes desired for specific applications, like premium quality frozen fish for sushi. No technology has gained wide acceptance for these ultra-low temperatures. R-23 could be used in theory but has extremely high GWP. Ethane would be technically suitable but is highly flammable. Not-in-kind technologies like air cycles are feasible, but rather inefficient and still very expensive. High-pressure HFC's like R-32 or R-410A are probably the best acceptable compromises.



©Diagram: Paul de Larminat

Fig.10

## 4.4. Retrofits

Among various constraints in the retrofit of existing systems, the capacity must remain similar; operating pressures should not be significantly higher than the reference refrigerant, and the efficiency should not be lower, especially as the power supply is limited on board. Compatibility with materials, e.g. oils, must also be considered. For safety, flammable refrigerants cannot be used in systems initially designed for the non-flammable R-22.

Even with these constraints, acceptable blends can normally be found to retrofit small to medium sized D-X systems, but it is highly recommended to perform tests on pilot plants before proceeding to a larger scale.

The situation is much more difficult for large flooded systems. Retrofits from R-22 to ammonia are not feasible for material compatibility and safety reasons. Prior tests to retrofit to R-404A did not prove technically satisfactory, and are not desired anyway because of the very high GWP of this refrigerant. The use of HFC/ HFO blends is also highly problematic because their temperature glide is not desired in large flooded systems. So, at this stage, there is no proven solution to retrofit large flooded systems. For this reason, some vessels that still have a long expected life are being completely refurbished with new systems, especially ammonia/CO<sub>2</sub> cascades. The initial cost is high, but it can be cost effective thanks to better energy efficiency and increased productivity.

# 5 Development Perspectives and Challenges

Whether it be for new vessels, system replacement on existing vessels, or retrofits where feasible, technologies used on fishing vessels will have to shift to refrigerants with lower GWP. For new ships or for the refurbishment of existing vessels, adequate technologies are already available. Incremental vs. operating costs of new technologies compared to conventional ones should be carefully assessed for understanding economics and funding opportunities that can be offered through different international or local platforms.

The real and urgent challenge is the management of the existing fleet using R-22. These fishing vessels often have several tonnes of R-22 on board. Ships have a complex legal status as they can be built, flagged, operated and serviced in different places. Service is a major issue: recharging such large systems can consume a large share of the R-22 allocated to some of the insular countries, causing great difficulties in the implementation of their plan to phase out HCFCs. This raises technical, economic, legal and policy related issues.

Technically, retrofit solutions can be found in most cases for small to medium sized D-X systems, but not for the large flooded systems. Reducing the consumption of R-22 for service can be achieved with a combination of measures: better detection and repairs of leaks, retrofit of systems when possible, retirement of some existing ships, replacement of the systems of large vessels when it makes economic sense considering their remaining lifespan, and possible reclaim and re-use of fluid after end of life or retrofit. But large quantities of R-22 will remain needed anyway.

With more than 1,000 vessels of various nationalities fishing for tuna, in the Pacific Ocean, and even more globally, there is an urgent need to have mechanisms in place to monitor and control the consumption of all refrigerants used (UNEP 2016<sup>2</sup>, p. 120). This would ensure that countries, especially from Pacific Islands, could meet their obligations under the Montreal Protocol as well as other international or regional commitments that might be of relevance to other parties.

## Conclusions

R-22 is still the dominant refrigerant in marine off-shore refrigerated vessels. For small to medium sized D-X systems, short term solutions for new systems can be found using fluorinated fluids with medium GWP, mostly blends of HFCs and HFOs, some of which are non-flammable. Proper care must be taken in the design of these systems to account for the “glide” of these blends. These blends can also be considered to retrofit existing R-22 D-X systems.

As an alternative to R-22 for new large flooded systems, cascades using CO<sub>2</sub> at the low-temperature stage are very attractive. For the medium temperature stage of such cascades, ammonia is already widely used and has proven safe provided adequate training and operation procedures are implemented. Non-flammable alternatives, like indirect systems, are also feasible for the medium-temperature stage of cascades, and offer drastic reductions in the CO<sub>2</sub> equivalent of the charges. These technologies are adequate for new systems, but cannot be used to retrofit existing systems; blends with glide also are not a satisfactory option. Therefore, no satisfactory solution has been found yet for the retrofit of large flooded R22 systems. For fishing vessels that have a long lifespan remaining, complete replacement of the existing system is required. For older vessels, consideration can be given to continue using their R-22 systems until end of life.

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# COLD CHAIN TECHNOLOGY BRIEF

## REFRIGERATION IN FOOD PRODUCTION AND PROCESSING



*Acknowledgement: This Cold Chain Brief was prepared by Jacques Guilpart (IIR Section C President), has been reviewed by Jim Curlin and Ezra Clark experts from the UN Environment OzonAction and also several experts from the IIR commissions.*

# **IIR-UN Environment Cold Chain Brief on Refrigeration in Food Production and Processing**



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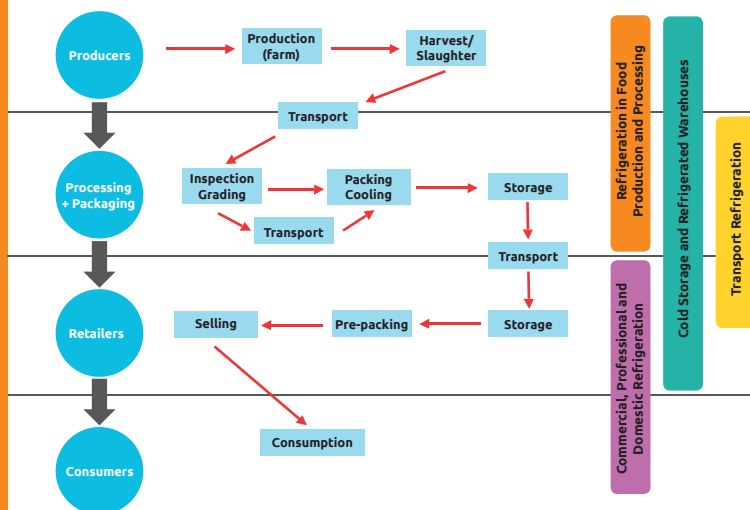
# 2 The Cold Chain

## Summary

For consumers, the cold chain is often associated with transport, retail and household refrigerators. But refrigeration is also and widely used in the agri-food industry for the storage of raw materials and final products, as well as for food processing. This brief gives a short overview of refrigeration applications in the industry. The refrigeration technologies in use are briefly presented, according to facility size and temperature requirements, and the problems relating to the use of refrigerants are also discussed. In conclusions, opportunities for sustainable refrigeration are briefly explored.

The “cold chain” refers to the various stages that a refrigerated product passes through, either until it is removed by a customer in a retail environment or unloaded from a delivery vehicle a few metres from its destination. From the moment a fruit or vegetable is harvested or an animal is slaughtered, the product starts to deteriorate. The deterioration of a product can be slowed by reducing the temperature at which it is stored. In fruits and vegetables, this slows down metabolic processes, which, in turn, slows spoilage. Reduced temperatures slow the growth of potentially harmful bacteria in animal products that are stored at frozen temperatures, allowing them to be shipped all over the world with minimal food safety risks. It is important that suitable temperature control be maintained from as soon as is feasible to as close as possible to consumption. From the raw materials stage to the various distribution storage facilities a commodity passes through, transport refrigeration keeps it at the temperature required to maximise storage life and quality for many days, weeks and months between cold storage facilities.

**The Cold Chain**



©Diagram : Judith Evans and IIR

Fig.1

The cold chain is often quite complex, with foods being chilled or frozen on more than one occasion. Worldwide about 400 million tonnes of food are preserved using refrigeration. The overall volume of cold stores (refrigerated warehouses) around the globe is about 600 million m<sup>3</sup>. The IIR estimates that the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion, including 1.5 billion of domestic refrigerators. 90 million of commercial refrigerated equipment (including condensing units, stand-alone equipment and centralized systems) are operating in the world. There are also 4 million refrigerated road vehicles (vans, trucks, semi-trailers or trailers), 1.2 million refrigerated containers (reefers) and 477,000 supermarkets, with a footprint ranging from 500 to 20,000 m<sup>2</sup> in operation and where 45% of the electricity consumed is used by refrigeration equipment (IIR, 2015<sup>1</sup>).

<sup>1</sup>IIR, 2015. 29<sup>th</sup> Note: The Role of Refrigeration in the Global Economy.

## 1 Introduction

Some of the food products we eat can be consumed “as is”, meaning with minimal processing. For instance, fruits and vegetables can be eaten raw (e.g. apples, oranges, lettuce) or following preparation and, possibly, cooking (e.g. beans, potatoes, yams). In some cases, the preparation and cooking may be done in food processing plants. This is also true for meat products, the difference being that meat is generally consumed cooked (e.g. steaks, stews) or following a specific process (e.g. cooking for ham, grinding for sausages). In all cases, especially those involving processed food, refrigeration is necessary to preserve and maintain the microbial, nutritional and gustative qualities of food.

# 3 Overview of Refrigeration of Food Products

An efficient cold chain starts very early in the supply chain: it begins with picking or harvesting for fruits and vegetables, and with slaughtering for meat products. The level of necessity for early refrigeration varies depending on the nature of the food.

## 3.1. Precooling

### 3.1.1. Fruits and vegetables

Rapid cooling is necessary to quickly slow the metabolism of these living products and extend their life: the quicker the temperature is reduced, the better the results will be.

Different techniques can be recommended depending of the nature of the product: pulsed air is used for the majority of products, immersion or hydrocooling is used for small fruits (e.g. cherries, berries), and vacuum cooling is used for leafy greens (e.g. lettuce, spinach). Note that for the blast air system, special care has to be taken to make sure the air is evenly distributed inside the pallets and stacks. Therefore, it is recommended to use curtains and/or tarpaulins that force the cold air to pass into the stacks (as shown in Figure 1, on left) and to also apply spacers between layers of the product.

### 3.1.2. Meat products

Blast air systems are used in order to cool the surfaces of the carcasses, preventing the growth of harmful bacteria and microorganisms. In addition the rapid surface cooling reduces moisture/weight loss. Unless carcasses are electrically stimulated it is recommended that a period of exposure to moderate cold (10 – 12°C) is applied before lowering the temperature down to chilling levels in order to avoid the risk of cold shortening, which can occur when a carcass is exposed too early to a temperature that is too low.



Fig.3

### 3.1.3. Eggs and dairy products

Even if the shell surface of the egg is necessarily contaminated after spawning (passage through the cloaca of the hen), the interior of the egg remains sterile as long as the shell is not broken or split. For this reason, some countries recommend to keep eggs at room temperature during transport and sale to avoid possible condensation on the surface of the shell due to temperature fluctuations, which would be favourable for the development of germs.

For dairy products, cooling the milk after milking is essential to obtain a quality raw material. This cooling is done in specialized tanks, able to lower the milk to 4°C in less than 2 hours.

## 3.2. Chilling

After precooling, the food product has to be chilled and maintained at the adequate temperature.

### 3.2.1. Fruits and vegetables

Chilling can be carried out in specific devices such as chilling tunnels, but it is usually done in classic cold rooms equipped with adequate ventilation (Grolee and Delaunay, 1993<sup>2</sup>), sometimes in modified atmospheres (Leteinturier, 1999<sup>3</sup>).

The chilling and conservation temperatures depend on the sensitivity of the product:

- For high-sensitivity products, (e.g. mangoes, melons, ginger, sweet potatoes, yams) temperatures below 8 – 12°C are not recommended, as they can cause metabolic disturbances that shorten the life of the goods.
- For medium-sensitivity products (e.g. tangerines, green beans, potatoes), it is possible to lower the temperature down to 4 – 6 °C, but not less.
- For low-sensitivity products, a temperature of 2 – 3°C, down to just above the freezing point is recommended.

Non-compliance with these recommendations can lead to injuries, such as surface pitting, discolouration, internal breakdown, failure to ripen, growth inhibition, wilting, loss of flavour, and decay. Whatever the sensitivity of the product, special care must be taken to ventilate the core of the pallet or the packaging in order to remove the gases and heat issued from the metabolic processes of the product.

All recommended storage temperatures for fruits and vegetables can be found in the Cold Store Guide (Grolee and Delaunay, 1993<sup>2</sup>) and on Postharvest website<sup>4</sup>.

### 3.2.2. Meat products

After the period of exposure to moderate cold required avoiding cold shortening, a low temperature (below 2°C) is recommended in order to prevent or inhibit the growth of spoilage microorganisms. Depending on the equipment of the slaughterhouse, this low temperature can be achieved in blast chillers or directly in classic cold storage rooms.

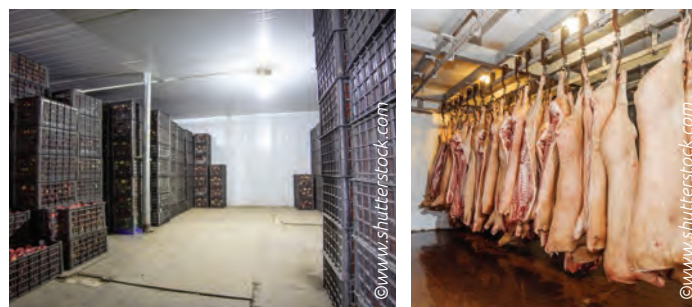


Fig.4

<sup>2</sup>Grolee, J. and Delaunay, J., (1993). Cold Store Guide. 3rd IIR edition, International Institute of Refrigeration (IIR), Paris, 204 p.

<sup>3</sup>Leteinturier, J., 1999. Preservation of fruit, vegetable and plant-derived products using refrigeration. Bull. IIR, 1999, vol. 79, 12 p.

<sup>4</sup><http://postharvest.ucdavis.edu/>



Fig.5: Typical frozen food products

Fig.6: Superchilled salmon (up) and supercooled garlic cloves (down)

### 3.2.3. Eggs and dairy products

For dairy products, a rigorous preservation of the cold chain is necessary to preserve the sanitary and organoleptic quality of the product until its consumption or its transformation. The conservation of processed dairy products (cheese, yoghurts, fermented milks, ...) has to be done at adequate temperature (4-6°C) in order to avoid the development of spoilage or pathogenic germs.

For eggs, conservation at higher temperature (8 – 10°C) could be adequate while the shell remains unbroken or unsplit. Nevertheless, the adoption of lower temperature permits to increase the shelf lives up to some months. Therefore, lower temperatures are recommended (4 - 6°C).

For both, these temperatures are maintained in classical cold storage rooms.

### 3.3. Freezing

Freezing is a process that consists in lowering the temperature of a product below its solidification point. Lowering the temperature of food products reduces the rate that chemical reactions occur. Freezing stops the metabolism of the fruit and vegetable products, and as long as the product remains frozen, it allows for very long storage durations.

In most cases, this process takes place in specific equipment designed to provide low temperatures and high air velocities (typically -35°C to -45°C and 3 to 7 m s<sup>-1</sup>) in order to ensure rapid freezing of the product. Following that, the product is stored at low temperature, (below -18°C) as required by international standards (FAO, 2008<sup>5</sup>).

### 3.4. Supercooling and superchilling

New processes for food storage have recently appeared in the cold chain. These processes are supercooling (lowering down the temperature of a food product just below its freezing point, but without ice formation) and superchilling (partial freezing of a food at a temperature just below its freezing point). These techniques have been adapted to animal products such as salmon and pork, and extend the shelf life of the product considerably (Kaale, 2011<sup>6</sup>). However, difficulty in defining and maintaining the adequate temperatures for these processes limits their uses to high-technology industries and refrigerated transporters.

### 3.5. Other food processes that require refrigeration

While refrigeration is generally known as an essential part of the food chain (preservation and storage), it is also used in many other industrial food processes that deliver high-quality products. The following is a non-exhaustive list of these processes:

- Crystallisation of fat for the texturisation of butter, margarines and some soft cheeses.
- Cryoseparation of undesirable components; such as tartaric acid in white wines and champagne.
- Cryoconcentration of components, as is done with fruit juices
- Lyophilisation (freeze-drying) of goods and drinks, most commonly coffee.



Fig.5



Fresh

Refrigerated



Supercooled

Frozen

Fig.6

<sup>5</sup>Food and Agriculture Organization of the United Nations (FAO), 2008. Code of Practice for the Processing and Handling of Quick Frozen Foods CAC/RCP 8-1976.

<sup>6</sup>Kaale, L. D., 2011. Superchilling of food: A review. Journal of Food Engineering. Volume 107, Issue 2, December 2011, Pages 141–146.

# 4 Industrial Refrigeration and Food Processing

Refrigeration is widely used in facilities for the storage and the processing of foods. The refrigeration systems and the cold distribution loops used in facilities operate according to the required temperatures and capacities.

## 4.1. Small facilities

Refrigeration is generally ensured by classic single-stage direct expansion systems. Piston/reciprocating compressors are widely used, and the refrigeration is produced by the refrigerant itself. These systems offer advantages since they are simple, reliable, the least expensive, and easy to implement and maintain.

## 4.2. Larger facilities

Research in high energy efficiency refrigeration technologies has led to the development of other adapted technologies, although they are more expensive in terms of investment and maintenance.

- For chilling, single-stage systems with flooded evaporators are recommended. The use of a secondary refrigerant (a coolant such as propylene glycol) for cooling distribution dramatically reduces the use of the primary refrigerant.
- For freezing, two-stage refrigeration systems (often with a screw and/or piston compressor in series) with flooded evaporators are often used and recommended.
- For chilling and freezing, screw compressors are often used because of their high ratio refrigeration capacity / overall dimension, even if large piston compressors can easily do the job.



Fig.7



Fig.8

# 5 Current Refrigerants Used and Potential Alternatives

Refrigerants used for cooling production depend on the size of the facility and the required temperature.

## 5.1. Small facilities

Non-flammable refrigerants with low toxicity are widely used, such as those belonging to the family of hydrofluorocarbons (HFCs). Due to their high Global Warming Potential (GWP), EU and international regulations on climate change (Kigali amendment) require countries to progressively reduce or phase out their use (IIR, 2015<sup>7</sup>), (EU F\_gas regulation, 2014<sup>8</sup>)

Alternatives to HFCs could include the use of low-GWP refrigerants and/or blends of refrigerants adapted to the required temperature. These blends are tailored to offer the best compromise between environmental impact, safety, and energetic performances. On the other hand, the majority of these blends have very high glide. For some applications, this particularity may cause some problems and require specific care.

Other possible alternatives that are beginning to be developed in small facilities include (RealAlternatives, 2015<sup>9</sup>):

- The use of hydrofluoroolefins (HFOs), a family of refrigerants with a very low GWP. The availability, current cost, and mild flammability behaviour of these refrigerants limit their widespread use. In addition, the long-term accumulation of their decomposition residuals in the environment must be checked and studied.
- The use of hydrocarbons (e.g. Isobutane, Propane) is possible, but only for very low refrigerant charges, due to their high flammability.
- The use of carbon dioxide is developing. While the intrinsic performances of this refrigerant are lower than those achieved with other fluids, the low environmental impact as well as the progress made in the designing of CO<sub>2</sub> loops makes this a potentially sustainable alternative, especially in temperate climates (IIR, 2000<sup>10</sup>).

<sup>7</sup>IIR 26<sup>th</sup> Informatory note Note, 2015. Overview of Regulations Restricting HFC Use, Focus on the EU F-Gas Regulation, January 2015.

<sup>8</sup>F-gas Regulation n° 517/2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 - 16 April 2014.

<sup>9</sup>RealAlternatives, (2015). IIR – IoR Life European project. Available at: <http://www.realalternatives.eu>

<sup>10</sup>IIR 15<sup>th</sup> Informatory Note, 2000. Carbon dioxide as a Refrigerant , February 2000.

Fig.7: Typical refrigeration units in a small-sized facility (left) and a medium-sized facility (right)  
Fig.8: Typical refrigeration unit in a large-sized facility

Fig.9: Typical two-stage liquid-vapour separator systems used for industrial refrigeration  
 Fig.10: Typical industrial refrigeration facilities based on secondary refrigerant loop system (up) and two-stage ammonia-CO<sub>2</sub> system (down)

## 5.2. Large facilities

As a rule, ammonia is generally used. Despite certain characteristics of this refrigerant, (e.g. toxicity) it can be used in large cooling production loops for a long time without any other constraints than those imposed by their toxicity. The adoption of specific design and maintenance regulations can reduce risks and create safer facilities (Pearson, 2008<sup>11</sup>).

For freezing, the use of two-stage systems with liquid-vapour separation vessels and screw compressors remains a standard.

Given the low GWP of ammonia, adoption of this refrigerant is often the best option. When it comes to reducing the hazards related to this refrigerant, some approaches have been used for a long time, while others have been in development recently:

- For chilling, the use of a cooling distribution loop based on a secondary refrigerant (a coolant such as propylene glycol) is a technology that has existed for a long time. It significantly reduces the quantity of ammonia present in the system, and therefore dramatically improves the safety of the facility.
- For freezing, the use of two-stage cascade systems with, for instance, HFC-R134a or ammonia in the high-temperature stage and CO<sub>2</sub> in the low-temperature stage also reduces the ammonia charge.
- The progress made in designing CO<sub>2</sub> loops has increased the use of full CO<sub>2</sub> systems, especially for freezing and low-temperature warehouses.

**Table 1: Summary of current and alternatives refrigerants**

Refrigeration in Food Production and Processing		
Types of facilities	Current higher GWP refrigerants (GWP kg-CO <sub>2</sub> )	Alternative lower GWP refrigerants (GWP kg-CO <sub>2</sub> )
Small	HFC-134a (1360), HCFC-22 (1810), HFC-404A (3920), HFC-407C (1920)	R-744 (1), HC (1.8 – 20), HFO-1234 yf and ze (<1-2), Low GWP blends HFC-HFO (< 1300)
Large	R-717 (0), HFC-404A (3920), HFC-507A (3990), HFC-134a (1300)	R-717 (0); R-744 (1)



Fig.9



Fig.10

<sup>11</sup>Pearson, A, 2008. IIR guide on Ammonia as a Refrigerant. 3rd IIR edition, International Institute of Refrigeration (IIR), Paris, p.88.



# 6 Development Perspectives and Challenges

Thanks to their performance, compactness and reliability, compression–expansion systems with phase-change refrigerants have been used for more than a century, and they will probably continue to be used for a long time.

## 6.1. Technical challenges

The real challenge is to develop and use refrigerants with high energetic performances, low environmental impacts and low hazard potentials (e.g. for flammability, toxicity). While a large variety of refrigerant blends are on the market, a “universal” refrigerant has yet to be discovered, and will probably never be discovered.

Alternative technologies, such as absorption and adsorption systems, have been developed in the past and continue to be the subject of research. At present, these systems have very high inertias and remain difficult to control in facilities that have large refrigeration loads. Investment in these systems is also higher compared to conventional systems, and there are few technicians qualified to provide maintenance for them.

## 6.2. Related driving policies

Refrigeration and Air Conditioning Industry witnessed considerable development and modernization in the last 3 decades partly as result to the international environmental policies where many refrigerants that have been used efficiently for decades, are held responsible to the Ozone Layer Depletion as well as Global Warming. The phase-out of ozone depleting substances (ODSs), under the Montreal Protocol, triggered significant changes in the industry moving towards alternative refrigerants and technologies that has zero-ODP (Ozone Depletion Potential).

In October 2016, the Kigali Amendment to the Montreal Protocol brought another dimension to the mandate of the Montreal Protocol by adding the control of production and consumption of hydrofluorocarbons (HFCs) under its mandate which will have major contribution towards the fight against climate change. Control of HFCs production and consumption will add to the climate benefits already achieved by the Montreal Protocol through the phase-out of ODSs including CFCs and HCFCs. The emissions of HFCs are also listed within the group of GHGs (Greenhouse Gases) under the Climate related conventions i.e. Paris Agreement and previously the Kyoto Protocol. However, actions to specifically control HFCs emissions within the climate regime are not yet set except for reporting requirements under the UNFCCC (UN Framework Convention on Climate Change).

The refrigerant climate impact of refrigeration equipment depends on direct and indirect effects. The direct effect is from its GWP (Global Warming Potential) and amount of a refrigerant emitted to the atmosphere (either from a leak, accident, or from improper handling or disposal). The indirect effect is associated with the energy consumed during the operation of equipment which, over its lifetime, occurs as a result of the CO<sub>2</sub> (CH<sub>4</sub> to lesser extend) produced by fossil fuel power plants, and is commonly greater than the direct effect. Minimizing direct and indirect impacts, of all types of refrigerants, emissions should be addressed through improved design, better field commissioning and main-

tenance practices, sound decommissioning procedures and enforcement to local relevant standards and regulations.

There are several principal organisations developing standards related to the refrigeration and air-conditioning sector. The UNEP International Standards in Refrigeration and Air-Conditioning booklet (UNEP, 2014<sup>12</sup>) summarises the main international standardisation organisations and provides some examples of national and regional standards organisations.

The cold chain sector is one of the most important but overlooked business segments in terms of being addressed in a holistic approach. This is because it crosscuts with different economic, social and technical areas i.e. food industry, health, refrigeration, transportation, tourism, etc. The norms and directions for cold chain technology selection that has less environmental impact, energy efficient operation and affordable economics is scattered amongst different groups and entities within the same country. In September 2015, International Community adopted the 2030 Sustainable Development Goals (SDGs) stipulating Goal #2 «Zero Hunger» as the second global goal which needs to be achieved by 2030. This automatically means the urgent need to efficiently manage the portfolios of «Food Security» & “Food Waste” which depends on the cold chain capabilities. While this goal can be noted as the main goal with direct relation to cold chain, other goals are also connected to the cold chain business i.e. Goal #3: Health and Wellbeing, Goal # 9: Industry Innovation and Infrastructure, Goal # 12 Responsible Consumption and Production as well as Goal #13: Climate Action. Therefore, the integrated.

<sup>12</sup> UNEP, 2014. *International Standards in Refrigeration and Air-Conditioning. An introduction to their role in the context of the HCFC phase-out in developing countries.*

## Conclusions

Industrial refrigeration is the first step in the cold chain where food is processed and stored before transport, retail and consumption. The refrigeration sector faces several challenges relative to reliability, performance (reducing energy consumption), environmental impact (promoting the use of refrigerants with low Global Warming Potentials and taking safety issues into account), regulations and economic concerns. Solutions for providing sustainable industrial refrigeration systems depend on the size of the facility and on the required temperature levels. These solutions do exist, and they must be implemented. Only then may we continue to provide our world with safe, high-quality food and contribute to its development and welfare.

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# COLD CHAIN TECHNOLOGY BRIEF

## TRANSPORT REFRIGERATION



*Acknowledgement: This Cold Chain Brief was prepared by Richard Lawton (IIR D2 Commission President), has been reviewed by Jim Curlin and Ezra Clark experts from the UN Environment OzonAction and also several experts from the IIR commissions.*

# IIR-UN Environment Cold Chain Brief on Transport Refrigeration



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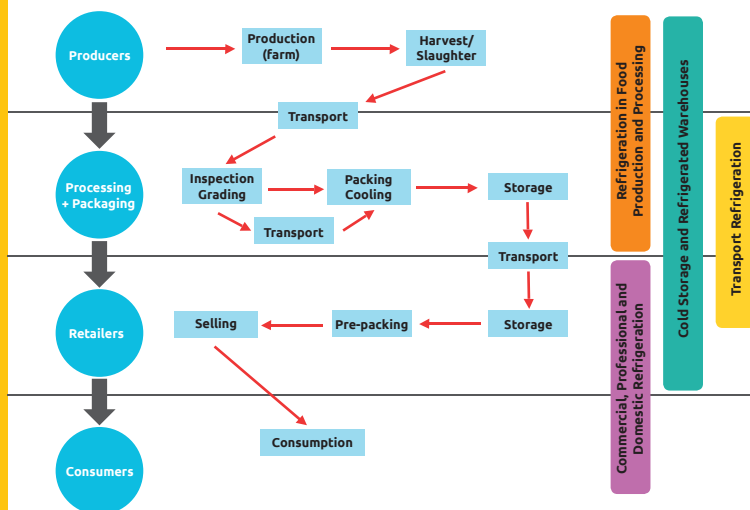
# 2 The Cold Chain

## Summary

This brief provides an overview of the main areas of transport refrigeration, some of the different systems used and the working fluids employed. It will go on to look at current trends in using alternative refrigerants and the direction the sector is moving in over a longer period. Future developments will be discussed along with the technical challenges facing designers as they attempt to reach the best balance between what the end user expects from a system and the framework determined by international treaties and regulations.

The “cold chain” refers to the various stages that a refrigerated product passes through, either until it is removed by a customer in a retail environment or unloaded from a delivery vehicle a few metres from its destination. From the moment a fruit or vegetable is harvested or an animal is slaughtered, the product starts to deteriorate. The deterioration of a product can be slowed by reducing the temperature at which it is stored. In fruits and vegetables, this slows down metabolic processes, which, in turn, slows spoilage. Reduced temperatures slow the growth of potentially harmful bacteria in animal products that are stored at frozen temperatures, allowing them to be shipped all over the world with minimal food safety risks. It is important that suitable temperature control be maintained from as soon as is feasible to as close as possible to consumption. From the raw materials stage to the various distribution storage facilities a commodity passes through, transport refrigeration keeps it at the temperature required to maximise storage life and quality for many days, weeks and months between cold storage facilities.

**The Cold Chain**



©Diagram : Judith Evans and IIR

**Fig.1**

The cold chain is often quite complex, with foods being chilled or frozen on more than one occasion. Worldwide about 400 million tonnes of food are preserved using refrigeration. The overall volume of cold stores (refrigerated warehouses) around the globe is about 600 million m<sup>3</sup>. The IIR estimates that the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion, including 1.5 billion of domestic refrigerators. 90 million of commercial refrigerated equipment (including condensing units, stand-alone equipment and centralized systems) are operating in the world. There are also 4 million refrigerated road vehicles (vans, trucks, semi-trailers or trailers), 1.2 million refrigerated containers (reefers) and 477,000 supermarkets, with a footprint ranging from 500 to 20,000 m<sup>2</sup> in operation and where 45% of the electricity consumed is used by refrigeration equipment (IIR, 2015<sup>1</sup>).

<sup>1</sup>IIR, 2015. 29<sup>th</sup> Note: The Role of Refrigeration in the Global Economy.

## 1 Introduction

Over time, the increased demand for temperature sensitive goods and the extension of shelf-life, has led to the development of diverse means of transport. This has been accompanied by technical developments designed to maintain unbroken cold chains. Transport refrigeration is by land, sea and air. Land transport being the most diverse comprise refrigerated semitrailers, containers rigid vehicles and small vans. Sea transport is now mainly refrigerated containers though entire refrigerated ships exist and significant numbers of fishing and fish processing vessels. Air transport times are short and the temperature control rudimentary.

# 3 Overview of Transport Refrigeration

Transport refrigeration is provided by various means as the commodity is moved along the cold-chain such as from the manufacturer to a distribution centre and then to stores from where it may increasingly be delivered to a customer's home, typically in a van or small truck. Regardless of the vehicle it is preferable to ship in bulk and having only one temperature required whenever possible as this incurs the least cost and complexity.

## 3.1. Refrigerated Vehicles

Refrigerated trucks come in many different shapes and sizes. They range from semi-trailers capable of carrying 26 - 33 fully stacked ISO pallets, commonly 1200x1000mm or 800x1200mm to smaller vehicles specially adapted by a manufacturer from standard cars or vans, sometimes in conjunction with a third party body builder who makes an insulated compartment to be mounted on the vehicle chassis, carrying only a few small cartons. The bodies of most truck and trailer refrigerated vehicles are insulated bodies of sandwich construction with an outer weatherproof protective layer, an interior frame of metal to provide structural rigidity surrounded by insulating materials and an inner protective layer. The inner protective layer often features "kick-plates" to protect against impacts from pallet-trucks and forklifts during loading/unloading as well as being equipped with various fixings. Smaller vans have the voids filled with moulded foams with mineral wool insulation around the smaller voids (Lawton *et al*, 2016<sup>2</sup>).

In the majority of developed countries such vehicles are subject to ECE/Trans/249 ("ATP") regulations (UN, 2015<sup>3</sup>) which require minimum insulation performance and heat extraction rates to ensure cold-chain integrity. There are two classes of insulation, IN and IR for frozen and chilled respectively. These correspond to heat transfer coefficients below  $0.70\text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$  and  $0.40\text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$ . The refrigeration equipment typically delivers cold air to the top of the body and the warmed air, having been drawn through the cargo, returns lower down. Multi temperature, multi compartment vehicles and their refrigeration systems are becoming increasingly common.

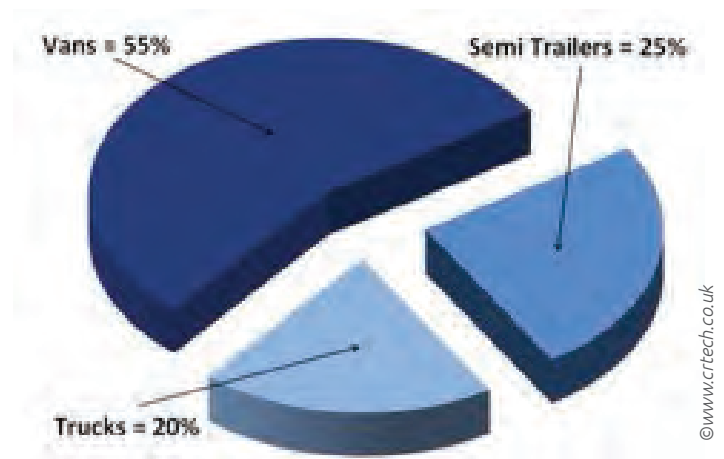


Fig.2

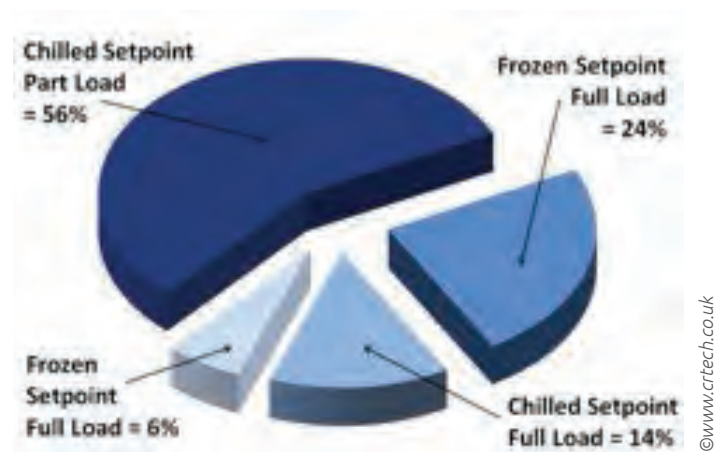


Fig.3

<sup>2</sup> Lawton, A. R., Mynott, T., Rhodes, C., 2016. *Performance Data of Insulated Panel on Refrigerated Equipment*. p.2, IIR ICC2016, Auckland, New Zealand.

<sup>3</sup> Cavalier, G., Devin, E., Michineau T., Vannson F. Thomas G., 2016. *Ageing of Refrigerated Truck Insulation*. p.2, IIR ICC2016, Auckland, New Zealand.

<sup>4</sup> Cemafruid, 2015. *Full load and part load reefer efficiencies for French energy certificate eligibility*.

<sup>5</sup> United Nations (UN), 2015. *Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be used for such Carriage*, Geneva, 978-92-1-139153-4.

Fig.2: Approximate Fleet Split (Cavalier *et al*, 2016<sup>3</sup>)  
Fig.3: Approximate Operating Mode Time Split (Cemafruid<sup>4</sup>)

### 3.2. Refrigerated Air Cargo

Air cargoes are used to transport a variety of vegetables and flowers with shorter storage lives to their destinations. Pharmaceutical cargoes are also common where cargo holds are typically kept between 15°C and 25°C (WHO, 2014<sup>6</sup>) with additional temperature control provided by passive or active systems. Passive systems are insulation media around the commodity which aim to reduce the influence of the surrounding air. Active systems are also packaged around the commodity but they contain refrigerants such as dry ice or phase-change materials (eutectic) to further reduce the rate at which a cargo warms or cools. Due to strict rules set by aeronautic regulatory bodies it is not viable to have refrigeration systems such as in road or container systems due to the levels of redundancy and risk minimisation required which drive costs up exponentially. Weight is also at a premium, as is space due to aerodynamic considerations when designing airplanes which are prioritised over the ability to quickly load vast amounts of cargo.

### 3.3. Intermodal Refrigerated Containers

Intermodal refrigerated containers are filled with commodities at or near to the source, typically carrying either live commodities to undergo ripening before sale or frozen cargoes to be further processed by a plant based near to the destination port. They are then shipped on large container carrying vessels with voyages lasting between a few days to five or even six weeks. During the voyage, the containers on deck can be exposed to hot and humid equatorial temperatures near the equator and then experience freezing and dry conditions when crossing the northern hemisphere, for example.

Containers are made to the principles of ISO standard 1496 which stipulates dimensions and other design-critical criteria. It is important for manufacturers to ensure compatibility with equipment such as cranes, lifting trucks, transport chassis etcetera all over the world. Such containers have ISO corner castings, T-bar floors to ensure airflow (required for break-bulk stows), lock-bars on the doors, drain holes, fresh air ventilation and sophisticated microprocessor controllers. The equipment is usually removable (integral), mounted with bolts and feature forklift pockets to allow a severely damaged unit to be changed. One company produces an integrated system which is inseparable from the container. Whilst this has the advantage of reducing heat leaks, and therefore power consumption, it also means that it is not possible to replace the refrigeration system should it become heavily damaged. The overwhelming majority of containers are either 40' or 20' long with 40's being common in standard and "high-cube" varieties. Many other designs are covered by ISO 1496 however these are rarely seen.

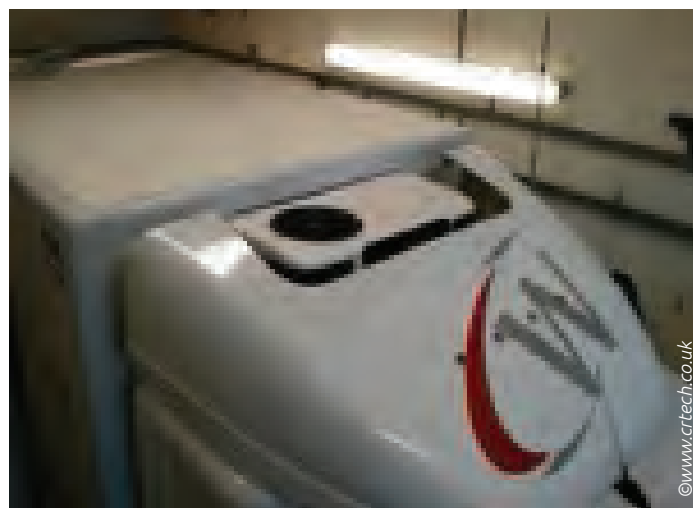


Fig.4



Fig.5



Fig.6



Fig.7



Fig.8



Fig.9

- Fig.4: Over-Cab Unit
- Fig.5: Nose Mounted Unit
- Fig.6: Inside a Home Delivery Vehicle
- Fig.7: Eutectic System
- Fig.8: Insulating Cover
- Fig.9: Insulating Packaging

<sup>6</sup>World Health Organisation (WHO), 2014. Temperature-Controlled Transport Operations by Road and by Air, Technical Report Series 961. WAS/14.598 Supplement 12, Annex 9, p15, WHO Press, Geneva, Switzerland.

# 3 Overview of Transport Refrigeration

## 3.4. Intermodal Container Controlled Atmosphere and Humidity Control

Many live cargoes, such as fruits, require fresh air venting to prevent gas build-up becoming detrimental. Relative humidity control is incorporated to modern systems. As fruits metabolise they not only produce heat but also increase CO<sub>2</sub> and decrease O<sub>2</sub> levels. Some systems are available which can be retro-fitted to equipment to allow precise control of these levels. One such example is seen in Figure 14 which is installed into the evaporator access panel of a compatible system. An example is shown in Figure 15 with the evaporator access panel at the upper right side opposite the fresh air ventilation panel. The storage life of some cargoes is greatly increased with low O<sub>2</sub> and high CO<sub>2</sub> levels.

## 3.5. Refrigerated Trains

Intermodal containers have now largely replaced the refrigerated trains of the first half of the twentieth century. "Freezer cars" were common in America until the 1950s as they allowed access to meat that didn't require curing – a novelty at the time. The American railroads were used to haul cargoes of frozen, hung meat across the sparsely spread towns and cities. Refrigeration was achieved using only dry-ice and other simple eutectic or phase-change solutions. More recently new routes have emerged, mostly connecting Russian terminals to others in the Middle East and the Asia-Pacific region, again due to the vastness of the countries. Containers are loaded onto ISO chassis-cars and regularly carry goods between Russia and countries such as China and Iran and its Middle Eastern neighbours.

## 3.6. Reefer Ships

The number of reefer ships is declining in favour of container ships. Many reefer ships have four refrigerated holds and deck space and power supplies for containers. Older vessels are often refurbished to be more accommodating to containers. A side-loading system for the holds to allow simultaneous unloading of the holds and containers is one such example. Small reefer ships often dedicated freezers are employed transferring the catch from fishing vessels to their eventual markets.



Fig. 11



Fig. 12



Fig. 13



Fig. 14



Fig. 15



Fig. 16



Fig. 17

Fig. 11: Reefer Stack at a Terminal

Fig. 12: Two 20' Reefers Stacked

Fig. 13: HFC-134a System

Fig. 14 : CO<sub>2</sub> System

Fig. 15: Active Controlled Atmosphere System

Fig. 16: Reefer Ship

Fig. 17: Side Loading System



## 4 Current Issues and Market Trends

Whilst many people only experience refrigeration domestically, in chilled and frozen sections of supermarkets and possibly air conditioning, the cold chain to get the produce to them often goes unnoticed. Without developments in cold storage and transport throughout the production and distribution processes, the modern supermarket would look very different with many commodities imported long distances being either very expensive or unavailable.

Over the past decade, principally in developed countries the cold chain has been extended to the customer's doorstep as supermarkets and online distribution services competed for business and introduced home delivery services, increasing the amount of smaller delivery trucks in service. Global container numbers have also grown steadily as international transportation has increased between developing countries. Growth is predicted to continue especially once developing countries adopt the cold chain for local distribution but this is to be expected as the population of the planet increases and demand for foreign produce grows, together with the desire to have foods available all year round which requires imports from abroad as fruit and vegetable crops depend on seasonal weather.

As developing countries obtain suitable infrastructure to facilitate implementation of a cold chain this will drastically reduce the amount of food waste and CO<sub>2</sub> impact associated with food production. Simultaneously there will be an increase of the CO<sub>2</sub> impact of vehicles and their cooling systems and therefore informed decisions need to be made on zero ODP refrigerant and low CO<sub>2</sub> emitting vehicles.

## 5 Current Refrigerants and Potential Alternatives

Currently a large percentage of the transport market is using either HFC-134a or HFC-404A refrigerants. HCFC-22 remains common outside Europe and North America and is also used on the majority of reefer ships. There are a few other options available however they are, currently, by no means common. The GWPs are from Kuijpers and Peixoto report (2014<sup>7</sup>).

Although the road transport sector has been quick to adopt alternative lower-GWP gases, the container industry has been much slower due to the technical and logistical challenges of ensuring the global availability of tools and supply chain of gases. Typically road transport operates over distances of a few hundred kilometres, returning to a base to be serviced. This does not happen with containers as they spend months at sea travelling around the globe.

Road transport has been quick to migrate from HFC-404A to HFC-452A for larger truck and trailer systems. Smaller systems currently using HFC-134a will possibly move to HFC-513A or propane much as commercial refrigeration is tending to. Some propane systems currently exist, though they are not common. The container industry has yet to change, however one of the large manufacturers has introduced a CO<sub>2</sub> system although only relatively small numbers have been sold. So far there have been minimal impacts upon the aerospace industry due to the systems used. Alternative technologies such as cryogenics and sorption are available and may become more widespread.

**Table 1: Summary of current and alternatives refrigerants**

Transport Refrigeration		
Types of transport	Current higher GWP refrigerants (GWP kg•CO <sub>2</sub> )	Alternative lower GWP refrigerants (GWP kg•CO <sub>2</sub> )
Refrigerated containers, road transport, trains	HFC-134a (1360); HFC-404A (3920), HCFC-22 (1810)	R-744 (1), HFC-452A (1950); HFC-513A (573); HC-290 (5)

<sup>7</sup>Kuijpers, L., Peixoto R., 2014. *Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee*, pp 54 – 57, 2014, UNEP Nairobi, Kenya.

# 6 Development Perspectives and Challenges

Currently both equipment manufacturers and standards committees are working to introduce systems and standards for safe operation of hydrocarbon, and other, flammable refrigerants. These have low GWPs, typically below five, although some resistance is present due to commercial interests. The marine industry is concerned about the dangers of such systems aboard vessels, particularly under deck where fires may start and spread easily. Various novel systems have been developed for road transport use which, although not yet significant in numbers, may one day mature into valid alternatives to reduce overall CO<sub>2</sub> equivalents.

## 6.1. Technical Challenges and Potentials

Equipment manufacturers have to balance safety and cost considerations within the transport industry. The cargo free-air spaces are small when stuffed, leaving potential dangers for workers opening the doors after a refrigerant leak on the evaporator section. Patent issues block much of the development of transcritical CO<sub>2</sub> vapour-compression cycles for transport applications leaving gas manufacturers to lead development and create new blends with low GWPs and excellent thermo-physical properties. Many blends are propene based and blended with common HFCs to produce a mid-GWP interim solution.

## 6.2. Related Driving Policies

Refrigeration and Air Conditioning Industry witnessed considerable development and modernization in the last 3 decades partly as result to the international environmental policies where many refrigerants that have been used efficiently for decades, are held responsible to the Ozone Layer Depletion as well as Global Warming. The phase-out of ozone depleting substances (ODSs), under the Montreal Protocol, triggered significant changes in the industry moving towards alternative refrigerants and technologies that has zero-ODP (Ozone Depletion Potential).

In October 2016, the Kigali Amendment to the Montreal Protocol brought another dimension to the mandate of the Montreal Protocol by adding the control of production and consumption of hydrofluorocarbons (HFCs) under its mandate which will have major contribution towards the fight against climate change. Control of HFCs production and consumption will add to the climate benefits already achieved by the Montreal Protocol through the phase-out of ODSs including CFCs and HCFCs. The emissions of HFCs are also listed within the group of GHGs (Greenhouse Gases) under the Climate related conventions i.e. Paris Agreement and previously the Kyoto Protocol. However, actions to specifically control HFCs emissions within the climate regime are not yet set except for reporting requirements under the UNFCCC (UN Framework Convention on Climate Change).

The refrigerant climate impact of refrigeration equipment depends on direct and indirect effects. The direct effect is from its GWP (Global Warming Potential) and amount of a refrigerant emitted to the atmosphere (either from a leak, accident, or from improper handling or disposal). The indirect effect is associated with the energy consumed during the operation of equipment which, over its lifetime, occurs as a result of the CO<sub>2</sub> (CH<sub>4</sub> to lesser extend)

produced by fossil fuel power plants, and is commonly greater than the direct effect. Minimizing direct and indirect impacts, of all types of refrigerants, emissions should be addressed through improved design, better field commissioning and maintenance practices, sound decommissioning procedures and enforcement to local relevant standards and regulations.

There are several principal organisations developing standards related to the refrigeration and air-conditioning sector. The UNEP International Standards in Refrigeration and Air-Conditioning booklet (UNEP, 2014<sup>8</sup>) summarises the main international standardisation organisations and provides some examples of national and regional standards organisations.

The cold chain sector is one of the most important but overlooked business segments in terms of being addressed in a holistic approach. This is because it crosscuts with different economic, social and technical areas i.e. food industry, health, refrigeration, transportation, tourism, etc. The norms and directions for cold chain technology selection that has less environmental impact, energy efficient operation and affordable economics is scattered amongst different groups and entities within the same country. In September 2015, International Community adopted the 2030 Sustainable Development Goals (SDGs) stipulating Goal #2 «Zero Hunger» as the second global goal which needs to be achieved by 2030. This automatically means the urgent need to efficiently manage the portfolios of «Food Security» & «Food Waste» which depends on the cold chain capabilities. While this goal can be noted as the main goal with direct relation to cold chain, other goals are also connected to the cold chain business i.e. Goal #3: Health and Wellbeing, Goal # 9: Industry Innovation and Infrastructure, Goal # 12 Responsible Consumption and Production as well as Goal #13: Climate Action. Therefore, the integrated approach in addressing the cold chain challenges can lead to multi socioeconomic and environment benefits.

<sup>8</sup>UNEP, 2014. *International Standards in Refrigeration and Air-Conditioning. An introduction to their role in the context of the HCFC phase-out in developing countries.*

## Conclusions

The road and marine refrigeration industries face vastly different challenges with regard to regulatory compliance due to the global infrastructure required to keep container ships and ports working. National issues with bordering countries will have some impact on developing countries in the Middle East with regards to road transport however this will be minimal compared to the disruption faced by the owners and operators of intermodal containers. Air freight will not be significantly affected due to the stringent safety standards and risk-averse regulators of the aviation industry.

*Disclaimer : The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the UN Environment and the IIR concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the UN Environment and the IIR, nor does citing of trade names or commercial processes constitute endorsement.*



**CTTC REF Report**  
**ASHRAE Winter Conference – Chicago 2018**

January 19, 2018

**ASHRAE Refrigeration Committee (REF)**  
 Liaison Report to  
Chapter Technology Transfer Committee  
 2018 Winter Conference, Chicago

REF Liaison: Charles Hon  
 chon@truemfg.com

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**CTTC REF Report**  
**ASHRAE Winter Conference – Chicago 2018**

**TOPICS**

- Refrigeration Update
- Chapter Program Support
- Advance Chapter Interest in Refrigeration

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**CTTC REF Report**  
**ASHRAE Winter Conference – Chicago 2018**

Tuesday, January 23 9:45 AM - 10:45 AM Workshop 5 (Advanced)

**Status of Standards in Europe and the Relation to IEC,  
 ISO in View of the Application of Low GWP  
 Refrigerants**

Room: Monroe

1. Changes and Work in Progress in IEC 61D and IEC 61C Related to Implementation of Low GWP Substances  
 Brian Rodgers, Underwriters Laboratories, Northbrook, IL
2. Changes and Work in Progress in European Standards for Low GWP Substances and Relation to ISO and IEC  
 Els Baert, Member, Daikin Europe NV, oostende, Belgium

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**CTTC REF Report**  
**ASHRAE Winter Conference – Chicago 2018**

Tuesday, January 23 11:00 AM - 12:30 PM Seminar 45

**What In The World? Global Refrigerant Regulations  
 Explained By Experts from Around the Globe**

Room: Red Lacquer (4th Floor)

1. The Kigali Amendment: What Does It Actually Do and Why Should I Care?  
 Andrea Voigt, Member, The European Partnership for Energy and the Environment
2. US Refrigerant Regulatory Updates, ASHRAE Standard 15 and UL Safety Standards  
 Bill Hansen, P.E., Ingersoll Rand, and Jason Robbins, P.E., McDonald's
3. Refrigerant Regulations in Asia  
 Tetsuji Okada, Japanese Refrigeration and Air Conditioning Industry Association
4. Refrigerant Regulations in Developing Countries  
 Ayman Eltalouny, Member, OzonAction Programme at UN Environment, Manama, Bahrain
5. Refrigerant Regulatory Updates in Europe  
 Martin Dieryckx, Member, Daikin Europe NV, Oostende, Belgium

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**CTTC REF Report**  
**ASHRAE Winter Conference – Chicago 2018**

• **REF Review of Position Documents**

**“ASHRAE Position Document on  
 Refrigerants and their Responsible  
 Use”**

Updated February 2017

**ASHRAE Guide for Sustainable  
 Refrigerated Facilities and Refrigeration  
 Systems (1634 RP)**

Due to be Published Soon

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**CTTC REF Report**  
**ASHRAE Winter Conference – Chicago 2018**

REF Webpage: [www.ashrae.org/refrigeration](http://www.ashrae.org/refrigeration)

**REF Operations**

- Recent Meeting Minutes
- Manual of Procedures, Rules of the Board, REF Reference Manual
- Members First! Newsletters
- REF Liaison Report to CTTC

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CTTC REF Report  
ASHRAE Winter Conference – Chicago 2018

- REF Webpage with Links
  - REF Resources/Chapter Program Support
    - To Support Chapters, REF has Developed Refrigeration-themed Program Materials
      - "Tips on Hosting Successful Refrigeration-focused ASHRAE Chapter Meeting"
      - ASHRAE Distinguished Lecturers (DL) list (edited to include only Refrigeration Topics)
      - ASHRAE Refrigeration Speakers list (expanded for improved geographic coverage in developing countries)
      - Kindred Refrigeration Organizations

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CTTC REF Report  
ASHRAE Winter Conference – Chicago 2018

- REF Webpage
  - Refrigeration Technology Awards by REF
    - Recognize the Designer and Owner of the Refrigeration Project exhibiting the Best Innovation and/or New Technology with Links to:
      - "Milton W. Garland Commemorative Refrigeration Award for Project Excellence"
      - "Refrigeration Comfort Cooling Award for Project Excellence"
      - Awarded at Plenary Session during Annual Conference

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CTTC REF Report  
ASHRAE Winter Conference – Chicago 2018

- Chapter Program Support – Efforts Underway
  - Encourage Expert Refrigeration Speakers for DL Program
  - Encourage Refrigeration Programs with broad appeal to Chapters
  - Develop list of Refrigeration Programs and Speakers with wide appeal

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CTTC REF Report  
ASHRAE Winter Conference – Chicago 2018

- Advance Chapter Interest in Refrigeration
  - REF seeks to promote Refrigeration Education and Training for Students and Seasoned Practitioners
    - Technology Transfer Programs
      - Refrigeration Programs at ASHRAE Conferences
      - "George C. Briley ASHRAE Journal Award"
        - Best Refrigeration-related Article
        - Awarded at REF Meeting, Winter Conference

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CTTC REF Report  
ASHRAE Winter Conference – Chicago 2018

- Advance Chapter Interest in Refrigeration
  - REF continues to work with and thru CTTC to Identify and Develop Resources and Implement Programs to enhance Chapter Refrigeration Activities including:
    - Work with the TCs to develop Hands-on, Low Cost Refrigeration Projects for College Lab Classes
    - Present Seminars at ASHRAE Conferences on Refrigeration Topics
    - Promote and solicit applications for Milt Garland, Comfort Cooling, and George Briley Refrigeration Awards
    - Submit recommendations to CTTC for PAOE criteria for Chapter Refrigeration Activities
    - Strongly encourage RVCs to actively promote strong Chapter participation in the recently approved "R in ASHRAE" Award

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CTTC REF Report  
ASHRAE Winter Conference – Chicago 2018

**THANK YOU**

**For your Participation & Support  
of ASHRAE Activities**

12



## Regulatory Update

Refrigeration Committee Meeting - January 21, 2018

Karim Amrane

## Regulatory Outlook - DOE

- Pending final rules
  - Residential furnaces
  - Commercial water heaters
  - Commercial boilers
- Rulemakings expected to start in 2018
  - VRF products (ASRAC negotiations)
  - ASHRAE 90.1 products (Datacom, DOAS)
  - Unitary large evaporatively and water-cooled
  - Commercial refrigeration equipment
  - Walk-in coolers and freezers
  - Commercial icemakers

## Regulatory Outlook – DOE

- Summer 2017
  - RFI inviting stakeholders to provide comments on existing regulations and other regulatory obligations that can be modified or repealed
- Fall 2017
  - RFI inviting stakeholders to provide feedback on market-based approaches to appliance standards (i.e. CAFE standards)
  - RFI inviting stakeholders to provide comments on rulemaking process
- Fall 2017
  - OMB released its unified agenda
    - DOE has indefinitely deferred action on 20 standards

## Regulatory Activities on Refrigerants - EPA

- Lawsuit - U.S. EPA SNAP
  - U.S. District Court of Appeals decision to limit use of HFCs under SNAP
    - EPA lacks sufficient authority to regulate HFCs under Section 612 of CAA
  - NRDC, Honeywell, Chemours filed petition for rehearing *en banc* of the panel decision
  - Vacatur of EPA's SNAP 20 rule will be held in abeyance until the D.C. Circuit makes a determination on the petition for rehearing, and potentially, on the merits of the case.

## Regulatory Activities on Refrigerants - EPA

- Lawsuit – U.S. EPA Section 608
  - Two industry coalitions have filed for judicial review and one has submitted a petition for reconsideration of final rule on refrigerant management requirements under Section 608 of the CAA.
  - On August 14, 2017, EPA announced its intention to propose revisions to certain aspects of the final rule.
  - EPA acknowledged Petitioners' concerns regarding the feasibility of meeting the January 1, 2018 compliance date

## Regulatory Activities on Refrigerants - ECCC

- Environment & Climate Change Canada (ECCC)
  - Proposed regulation published on October 18, 2017, in Canada Gazette part II
    - Effective around April 18, 2018
  - Full harmonization with U.S. EPA
    - Stand-alone medium temp refrigeration → GWP limit increased to 1400 (from 700), effective Jan 1, 2020
    - Centralized refrigeration system → GWP limit increased to 2200 (from 1500), effective Jan 1, 2020
    - Chillers → GWP limit increased to 750 (from 700), effective Jan 1, 2025
  - Implementation of Montreal Protocol phasedown on HFCs

## Regulatory Activities on Refrigerants - CARB

- California Air Resources Board
  - Short-lived climate reduction strategy approved
  - Regulations started in October 2017 – two rulemakings
  - Rulemaking #1
    - Proposes adoption of SNAP rules 20 and 21 – CARB will rely on EPA SNAP regulations if Court decision upholds rule 20
    - Regulation effective in mid to late 2018



## Regulatory Activities on Refrigerants - CARB

- Rulemaking #2
  - GWP < 150 – New refrigeration systems, refrigerant charge  $\geq 50$  lbs – effective 2021
  - GWP < 1500 – New refrigeration systems, refrigerant charge  $\geq 20$  & < 50 lbs – effective 2021
  - GWP < 750 – New air conditioning systems, refrigerant charge  $\geq 2$  lbs – effective 2021
  - GWP < 150 – New chillers (refrigeration and AC) – effective 2021
  - No production, import, sales, distribution or entry into commerce of refrigerants with GWP  $\geq 2500$  effective in 2020
  - No production, import, sales, distribution or entry into commerce of refrigerants with GWP  $\geq 1500$  effective in 2024
  - Regulation effective in mid-2019

## Regulatory Outlook – Safety Codes and Standards

- ASHRAE 15 proposed requirements for 2L refrigerants
  - Addendum d addresses “high-probability systems” in applications for human comfort
  - Addendum h, addresses machinery room applications
  - New requirements to address residential applications (ASHRAE 15.2)
  - Completion expected in 2018
- UMC
  - 2018 cycle completed – Proposal on 2L refrigerants was rejected
- IEC 60335-2-40
  - Revisions underway to include 2L refrigerants
  - Completion expected in 2018
- IEC 60335-2-89
  - Revisions underway to increase charge limit of class 3 refrigerants
  - Completion expected in 2018

## Montreal Protocol Developments

- Kigali Agreement
  - U.S. Senate ratification, unclear
- Multi Lateral Fund
  - ExCom Meeting - Bangkok (July 3-7)
  - ExCom Meeting - Montreal (November 13-17)
- Safety standards workshop - Bangkok (July 10)
- Open Ended Working Group (OEWG) – Bangkok (July 11-14)
- Meeting of the Parties (MOP) – Montreal (November 20-24)
- Issues
  - Energy efficiency (workshop during OEWG meeting in July 2018)
  - Refrigerant management
  - HFC-23 destruction
  - Codes and standards
  - MLF funding/implementation (\$540 million approved)



## Flammable Refrigerants Research

- AHRI Conducting (\$1.0 million) – (CARB \$0.3 million):
  - AHRTI-9007: Benchmarking Risk by Real Life Leaks and Ignitions Testing
  - AHRTI-9008: Investigation of Hot surface Ignition Temperature (HSIT) for A2L Refrigerants
  - AHRTI-9009: Leak Detection of A2L Refrigerants in HVACR Equipment
- ASHRAE conducting (\$1.2 million):
  - ASHRAE-1806: Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update
  - ASHRAE-1807: Guidelines for Flammable Refrigerant Handling, Transporting, Storing and Equipment Servicing, Installation and Dismantling
  - ASHRAE-1808: Servicing and Installing Equipment using Flammable Refrigerants: Assessment of Field-made Mechanical Joints
- DOE funding (\$3.0 million):
  - ORNL: Investigate the proper basis for setting charge limits of A2L, A2, and A3 for various types of products
  - NIST: Modeling tools for low-GWP refrigerant blends flammability

## Questions & Discussion

- **A2L & A3 Refrigerant Expedited Research Effort**

**Update 12/19/17:** Below is the latest status on the three projects that ASHRAE is leading on this effort.

- **RP-1806, “Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update”**

Cost: \$843,500 – Start Date: Jan. 2017

Current Contract End Date: Dec. 2017 – Expected End Date: **TBD**

Initial Est. Duration: 12 months – Current Est. Duration: **TBD**

Contractor: GEXCON US, Bethesda, MD - Principal Investigator: Scott Davis

Objective: This project is needed to understand the Severity of events where flammable refrigerants are ignited under different scenarios for various HVAC&R products. Such understanding will allow for the assessment of the overall risks of using flammable refrigerants in HVAC&R products, taking into account both event Probability and Severity. The first step in this effort is to develop a computational fluid dynamic (CFD) model that will accurately duplicate the physical test results from AHRTI project 9008.

Status: Since June 2017, P.I. has not been able to come up with a solution routine (Source Term) yet in his model that will accurately model how the refrigerant was released (Flashing liquid and condensation in release tube) in the AHRTI 9008 project. Until we can accurately simulate the results from the AHRTI project, we can't proceed to Task 2, which is the risk assessment work for various release and equipment scenarios so that this information can be used to update the standards.

**12/19/17 Update:** P.I. presented their results from Task 1 (Model Improvement, Calibration, and Validation) to the PMS on 11/14 and 11/17 and requested permission to proceed to Task 2 (Simulation Study). In Task 1, the P.I. looked at data from many previous projects done by others on flammable refrigerants and tried to match the results of those projects with his model. Each previous project used in Task 1 for matching had its strengths and weaknesses with respect to the the following factors that are used to determine a good fit for model validation: 1. Relevance and Context, 2. Spatial Scale, 3. Repeatability, Quality of Measurement, and 4. Availability of Data. **We are still waiting to learn if the PMS will allow the contractor to move on to Task 2.**

**1/8/18 Update:** **We are still waiting to learn if the PMS will allow the contractor to move on to Task 2.**

- **RP- 1807, “Guidelines for Flammable Refrigerant Handling, Transporting, Storing and Equipment Servicing, Installation and Dismantling”**

Cost: \$80,000 originally

Total Expected Project Value: **\$95,000**

Start Date: Mar. 2017 – Current Contract End Date: Aug. 2017

Expected End Date: **January 2018 with additional scope.**

Initial Est. Duration: 6 months – Current Est. Duration: 9 months

Contractor: Navigant Consulting Inc., Burlington, MA - Principal Investigator: William Goetzler

Objective: This proposed project will investigate current information related to installation practices as well as servicing and handling aspects for all equipment that use A2, A2L



and A3 refrigerants. There are varied skill levels that exist within the HVAC&R industry in the US, and introduction of flammable refrigerants could increase the need for specialized processes, training, and/or certifications as part of risk mitigation.

Status: P.I. provided draft final report to project monitoring subcommittee (PMS) in late July this year. PMS met to discuss draft final report on 8/16 and provided feedback and suggested edits to P.I.. One suggestion from the PMS was to add Canada as an additional country to the report, which was not originally included in the project work statement developed by AHRTI, but would be useful to the project.

**11/6/17 Update**: A revised draft of report was provided by P.I. to PMS on October 13, 2017 along with a funded extension proposal for the additional work needed to add the same country information for Canada to the report. The RP-1807 PMS unanimously approved the funded extension on 10/17/17. The project's sponsoring committee, MTG.LowGWP, approved the change via letter ballot vote on 10/25/17 by a vote of 22-0-0-3 (25). RAC has final approval authority over the proposed change order and they unanimously approved the additional work for \$15,000 on 11/3/17.

**12/19/17 Update**: Updated draft of final report, which now includes information on Canada, was submitted by the P.I. to ASHRAE for review on 12/13/17. PMS is now reviewing for approval. Expect to wrap up project in Chicago with MTG.LowGWP approval vote.

- **RP -1808, “Servicing and Installing Equipment using Flammable Refrigerants: Assessment of Field-made Mechanical Joints”**

Cost: \$115,000 plus \$50,000 cost share by contractor – Total Project Value: \$165,000

Start Date: May 2017 – Current Contract End Date: Oct. 2017

Initial Est. Duration: 6 months – Current Est. Duration: 8 months

Contractor: Creative Thermal Solutions, Inc., Urbana IL - Principal Investigator: Stefan Elbel

Objective: It is necessary to identify those joining techniques used in the HVAC&R industry that are prone to failure if precaution is not used during equipment installation, servicing and repair, particularly when using flammable refrigerants. The information generated from this project will be crucial to the development of ASHRAE Standard 15.2, which will specify the safe design, installation, operation and maintenance of residential air-conditioning and heat pump systems containing flammable refrigerants. In addition, the results of this research will inform proposed changes to ASHRAE Standard 15 and other relevant codes and standards regarding permissible types of joints to be used during field installation and repair of a wide range of HVAC&R equipment containing flammable refrigerants.

Status: Project started in May 2017 and is on track to complete in December 2017. No issues or problems noted so far.

**12/19/17 Update**: Polling now for PMS & P.I. meeting in mid-December to discuss progress.

**1/8/18 Update**: No PMS/P.I. meeting has been scheduled yet.

MTG.LowGWP ExCOM met on 8/15 to discuss the status of projects and plans for upcoming meetings. The recent court ruling preventing EPA from regulating HFCs using the SNAP rule was also discussed and the general consensus was that all work on A2L still needs to continue to proceed as planned and the A2L information is still needed in order to update standards.

**From:** [Ron Vallort](#)  
**To:** [Olesen, Bjarne](#); [Hayter, Sheila](#)  
**Cc:** [Vaughn, Michael](#); [Shockley, Nick](#); [Hammerling, Steve](#) ASHRAE/  
**Subject:** GCCA Liaison Information (LED lighting)  
**Date:** Wednesday, August 30, 2017 12:30:20 PM

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Bjorne,

Please see the informational item below regarding Energy Savings using LED Light Fixtures in Refrigerated Facilities. The information is an example of actual savings in replacing conventional light fixtures with programmable LED lighting.

Steve H. or Michael V. - Please send a copy of this information to the Current Chair of ASHRAE T.C. 10.5.

### **3PL Supply Chain Forum Digest for Tuesday August 29, 2017**

Aug 29, 2017 10:18 AM

We replaced T5 and T8 fixtures with ceiling mounted LED fixtures at a ratio of 2 LED fixtures for every 3 fluorescent fixtures removed.

Light levels with fewer LED fixtures are higher and whiter. Each fixture in our freezers (0F, -18C) and blast freezers (-22F, -30C) is equipped with an occupancy sensor. Rated energy consumption per LED fixture is 40% less. Occupancy sensor delivers another 40% to 50% depending on activity.

We're also estimating energy savings from reduced heat load at approximately 20%.

Ron Vallort

ASHRAE/GCCA Liaison

## Refrigeration Committee

Nick Shockley, Chair

Date:1/21/2018

Item #	MBO	Status	Date Due	Assigned To	Applicable Strategy #	MBO Comments	UPDATE
Included in Definition of Roles							
1	Develop and Expand Refrigeration Education & Outreach	OPEN	1/21/2018	Royal, Rule	1c, 3d	i) Broadcast info on Milton Garland comfort cooling & Briley Awards in ASHRAE Insights and Members Newsletter. Solicit award submissions from Chapters ii) Organize ALI Subcommittee. Assist in the development of programs for regional chapters on refrigeration concepts. Liaise with YEA. Royal developing course proposal with ALI. iii) Update position document on ammonia iv) revise Refrigerants and their Responsible Use PD	Awards will be publicized in Insights, on website REF exploring ALI course PD on Ammonia revision was approved by BOD Refrigerants PD was reaffirmed and is being revised.
2	Support of ASHRAE Developing Economy Objectives	OPEN	6/24/2018	Minor, Coulomb	4a, 4b, 3b	i) REF and UNEP co-sponsored workshops and/or seminars on environmental and safety concerns of alternative refrigerants for developing countries ii) Develop guidance on available alternatives or resources which promote energy efficient alternatives iii) Support dissemination of GRMI principles to developing countries	REF exploring deliverables requested from Ad Hoc report. Programs relevant to developing economies planned for Houston. ASHRAE is on GRMI steering committee.
3	Implementation of UNEP Partnership Goals	OPEN	Ongoing	Nair-Bedouelle, Robbins	4a, 4b	i) ASHRAE & UNEP will explore opportunities to promote responsible and sound management of refrigerants ii) ASHRAE and UNEP to cooperate and coordinate efforts related to energy efficiency in the buildings sector iii) ASHRAE through its Distinguished Lecturer (DL) program will work with UNEP to provide speakers to collaborative activities between UNEP and ASHRAE chapters/sections	Joint ASHRAE, UNEP, IIR conference on sustainable management of refrigeration technologies in mobile marine and fisheries (Bangkok 2017). Linked to MBO#2 deliverables Refrigerants awareness package low GWP program
4	ASHRAE policy commentary on REF related issues	OPEN	24-Jun-18	assign in Chicago		i) Recommend what positions, if any, ASHRAE should take on public policy where feedback is sought by the governing agency (EPA, DOE, etc.) ii) Present recommendations to Tech Council and/or ASHRAE BOD for review and approval	REF discussed in Chicago. Will comment on UN RTOC to model how REF can participate.
5	Effective communication and operation of the REF Committee	OPEN	Ongoing	Shockley, Dieryckx, past Chairs	2a, 2b, 2c	i) Assure Technical Committee alignment ii) Development of a Planning Subcommittee for REF (current and future leadership) iii) Continued collaboration with other REF related organizations	REF established subcommittee structure to help coordinate liaison activities and assignments. Liaisons with IIR, IIAR, GCCA, UNEP assigned. Liaising with ASHRAE TCs, SSPCs as well